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TO KNOWLEDGE.

Nº. XIII.

SKETCHES OF GEOLOGY

LONDON
WILLIAM PICKERING
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EDITORS' PREFACE.

THE Editors of the "Small Books" have been more than once requested to add Geology to the sciences which they have endeavoured to elucidate. It has been urged that it is at present incomprehensible to beginners, or persons who have not time for the reading long treatises: — that "Introductions" by different authors contradict each other;—that they are encumbered with technicalities,—that they tell nothing but facts that lead to no conclusions, &c. Now these allegations are not exactly true: for no science has to boast of clearer and better writers; the fault, therefore, it is likely, is more in the mind of the reader than in that of the writer; and the Editors of the "Small Books" would probably have no better success than their far abler predecessors, were they simply to confine themselves to the science; however they might divest it of technicalities, or however just might be their views. It is to the mind of the reader, therefore, that they will first address themselves, and by endeavouring to clear that ground, make way perhaps for other and better works: for it is evident that in so narrow a compass as they have prescribed to themselves, they can do little more than excite the appetite for knowledge:—to satisfy the craving, the reader must seek more substantial food than they are able to afford him. But this first step is often the most important and the most difficult; and as they have hitherto been cheered by a success which at first they hardly anticipated, so they are encouraged to persevere in their undertaking: and have not shrunk from the prescribed task, though conscious of the difficulty of doing justice to the subject in such small space.

There are two very natural feelings which almost imperceptibly affect the minds of most men with regard to this science, and which, having already full possession of the reader, render him unwilling rather than unable to comprehend its truths. The hopes held out to us by Holy Writ, are so exactly accordant with every wish that an unsophisticated mind would form for its future lot, that a very large proportion of those who depend upon them with implicit faith, have received them rather because they satisfy the longings of nature, than because they come supported by proofs that cannot be gainsaid. The

Apostle Peter foresaw this danger, and enjoined his converts to make themselves capable of giving *a reason for the hope* that was in them: but this most wise injunction has been more and more disregarded; even to the point, in many cases, of rendering men unwilling to seek proof, as though they considered themselves to be thus shewing a distrust of God's promises. So thought not St. Peter;—so thought not St. Paul when he exhorted Christians to prove or examine all things, and hold fast that which is good: or when he approved the Bereans, who anxiously worked out their own faith by trying "whether those things" which he preached "were so;" and this departure from the good and wise advice of the Apostles, has led to a faith which has been little else than an indolent prejudice. Men have believed because they wished to believe; or, worse yet, have given a cold assent to the faith of their fathers, because they were so taught in childhood. To ask such to examine the grounds of their belief, is to bid them encounter a fatigue which they are wholly unaccustomed to: from childhood up, they have submitted to authority; and the mind, untrained in the methods of reasoning, becomes bewildered, and shrinks from the unwonted toil. No human creature likes what is laborious, and deep thought is more fatiguing than any other corporeal exertion:—the brain is feeble, for want of wholesome exercise, and the task we would impose, is next to an impossibility. Thus the two great movers of human beings, hope and fear, or, in other words, pleasure and pain, array themselves against any science which may, *apparently*, clash with Holy Writ; for there will be fatigue in proving how much we can justly believe;—despair in abandoning our present faith.

Such persons as above described, find an easy way of partly satisfying themselves: they forswear science, lest it should shake their faith, and remain wilfully ignorant: and if it be urged to them, that Astronomy, or Geology, have great facts to stand on; reply, that "something more may yet be discovered, which will prove that the earth really is in the centre of the universe," or declare, that all the facts of geology, form but 'a sort of chaos, where nothing but contradictions are to be found; and that Neptunians, Plutonians, and the like, all had their followers;' and that 'one makes good his case, only till disproved by the opposing theorist.'

We gain nothing by attempts at explanation; for the hearer, in such cases, is determined not to understand, and it is even a vexation, should we be able to make out any point completely: it is therefore, requisite at first, to leave the science to find its own way, while we busy ourselves in smoothing the road for its advance. Now we have happily, in the words of an apostle, and he no mean one, the very use and extent of Scriptural inspiration laid down; "Continue," says he, to his pupil Timotheus, "in the things which thou hast learned, and hast been confirmed in;—knowing from whom thou hast learned, and because from a child, thou hast known the Holy Scriptures, which are able to make thee *wise unto salvation*, through faith, which is in Christ Jesus. All Scripture given by inspiration of God, is profitable for teaching, for reproof, for setting right, for education in righteousness, that the man of God may be perfected (*ἄρτιος ᾖ*,) thoroughly prepared for all good works." The Scriptures then, are intended to make us "wise unto salvation;" but there is no reason to expect that they will make us wise in natural philosophy. With regard to that we are left to ourselves; since, were the spur to mental exertion, afforded by the unexplored wonders around us, taken away by a special revelation, man would lose more than half the useful training which has been appointed for him here. There is nothing which so deadens the allurements of sensuality, or so withdraws us from the empire of the animal nature, as ample employment for both mind and body:

and what can afford such full occupation as the pursuits of science? An authoritative revelation from God himself would put an end to all enquiry: man would become indolent first, then sensual, then vicious:—we may therefore very reasonably conclude that no such revelation would be made. 'But,' it will be answered, 'such a revelation has been made: the first chapters of Genesis are a distinct account of the formation of the universe, and the mode of it.' The reply to this must be given by the Apostle. Such an account forms no part of the design of the writings inspired by God; and we have therefore good right to conclude, that as the prophets, when not ordered, like Ezekiel, to perform any typical act, proceeded in the affairs of life like other men;—so, when not commissioned to communicate to their fellow creatures something which might make them "wise unto salvation," they were left to detail what they knew, or had heard, as any other conscientious man would have done: with an honest care to examine and relate truly, what they saw or were told, but with no supernatural assistance to prevent those common errors which the best intentioned may fall into.

What have we to fear from the researches of science? That some thing shall be discovered which may prove that Moses, or subsequent writers, were not farther advanced in astronomy than the people of their time? This is no more than we were prepared to expect. That the real history of the foundation of the Universe may be found to differ from that given in the book of Genesis? This, according to the views above mentioned, does not invalidate a single word that can make us wise unto salvation. A fact in nature is a vestige of God's hand, and he cannot write one thing himself, and cause his prophet to write another. Then, if his prophet have written other than God has written, it is rational to enquire whether, in this case, it is likely that there should have been any divine dictation?—whether, in the points treated of, there is any thing of which the knowledge is requisite to our eternal happiness?—if there be not, the conclusion is fair that the writer spoke his own words, and related merely what he had heard, and supposed to be the truth. To advance new views in natural philosophy was dangerous, even in more enlighted times; witness the law of Athens, which made it a capital offence to promulgate novelties in astronomy;—it would have been an useless cruelty to have required that the doctrines of the Newtonian philosophy should have been preached to a prejudiced and rude people, with the probability that the scientific truth would have been sealed with the blood of the witness.

It would be wise if the very well intentioned persons who shrink from science, lest it should clash with their preconceived opinions, would consider that they can no more alter known facts by shutting their eyes to them, than they can blot out the sun by closing their shutters; the only result therefore of their plan of proceeding, is, that they may shake other men's faith in revealed religion. A person may be deeply versed in science but may not have attentively considered the arguments for and against revelation; for—the more the pity;—these seldom form a part of education. Present him the Gospel, radiant with truth, promising immortality, and preaching the purest of morality, and he will bow before a doctrine that must be of God: but tell him that, besides, and with this, he must receive various evident mistakes in science, and he will begin to doubt if the gospel itself be more than the work of a man of peculiarly happy talent, who had hit on these great truths by chance: for, he might urge, God cannot teach falsehood, and these mistakes in science certainly prove that *He* could not have dictated them. Thus, because a few well meaning, but illjudging persons mistake the object of inspiration, many may be led to disbelieve it altogether:—an evil result from what might be thought an innocent prejudice, were it not that in resisting the truth, we resist God, who IS TRUTH. Such a course cannot do other than end in evil, for all things having been framed for good by the Creator, if we in any way contravene his arrangements we lose some of the benefit which would otherwise have been ours.

Errors of this kind are so plausible that it is not easy to persuade those who hold them that they *are* errors. 'What harm can it do if I do not choose to know anything about this or the other science?' is a natural question; but all have more or less share in teaching the young: —ignorance leads to the teaching of error;—the child at last emerges from the cloud which has been spread over his understanding, and finds that there are facts contradicting what he has been taught as a sacred truth:—is this no harm? Will he not haply cast aside all, when he finds that a part is false? This has been urged before; but it can hardly be urged too often, until men become aware that they sin against God when they conceal any of his great truths from their fellow-creatures. St. Paul assures us that the unseen things of God are to be learned from the things which we see; it is therefore a contempt of Him to shut our eyes to the wonders of his creation, wherein we may read more of eternity, omniscience, and infinity than all the sermons in the world could teach us. It was when the Psalmist had contemplated the heavens, even with the small knowledge which his times afforded, that he exclaimed, shrinking under the sense of his own littleness,—Lord, what is man that thou art mindful of him?' and the modern astronomer, whose telescopes have added uncomputable spaces and numbers to the universe, *feels* what infinity is: while the geologist who traces backwards revolution upon revolution of this globe, constantly producing a state of things more and more fitted for an improved race of beings, may see in this progressive state one of the strongest arguments for a still continuing advance, and find between himself and INFINITE WISDOM room for a progress that may last through eternity.

TABLE

OF THE ORDER OF SUPERPOSITION OF THE DIFFERENT FOSSILIFEROUS STRATA AND GROUPS OF STRATA,

AS GIVEN BY PROFESSOR ANSTED.

Tertiary Period.

	British Rocks.	Characteristic Foreign Equivalents.
Superficial Deposits, or Pleistocene.	*Diluvium* and *Alluvium*. Superficial deposits of gravel and other transported materials covering the regularly stratified rocks in all countries, and sometimes stratified.	
Newer Tertiary, or Pleiocene.	*Till* of the Clyde Valley. Norwich or mammaliferous crag.	Newest Sicilian beds. Loess of the Rhine. Brown coal of Germany. Subapennine beds.
Middle Tertiary, or Meiocene.	Red crag. Coralline crag.	Basins of the Loire and Garonne. Basin of the Rhine. Molasse of Switzerland. Basin of Vienna.
Older Tertiary, or Eocene.	Bagshot sand. London clay.	Paris basin. Basin of Brussels. Freshwater beds of Auvergne in central France, and of the South of France.

Newer Secondary Period.

	British Rocks.	Characteristic Foreign Equivalents.
Cretaceous System.		Maestricht beds.
	Upper chalk (with flints).	
	Lower chalk (without flints).	
	Chalk marl.	Craie tuface.
	Upper greensand.	Pläner kalk.
	Gault.	
	Lower greensand.	Quadersandstein. Neocomien.

Middle Secondary Period.

Wealden Formation.	Weald clay.	
	Hastings sand.	
	Purbeck beds.	
Oolitic System.	Portland stone.	
(*upper.*)	Portland sand.	Lithographic limestone.
	Kimmeridge clay.	Argile de Honfleur.
(*middle.*)	Upper calc grit.	
	Coral rag.	Nerinæan limestone.
	Lower calc grit.	
	Oxford clay.	Argile de Dives.
	Kelloway rock.	
(*lower.*)	Combrash.	
	Forest marble.	Calcaire a polypiers.
	Great Oolite and Bradford clay.	Calcaire de Caen.
	Stonesfield slate and fuller's earth.	
	Inferior Oolite.	
	Calcareous sand.	
Liassic Group.	Upper Lias shale and marlstone.	
	Lower Lias shale	
	Lower Lias limestone.	

Older Secondary Period.

	British Rocks.	Characteristic Foreign Equivalents.
Upper New Red Sandstone, or Triassic System.	Saliferous red and variegated marls.	Keuper (Marnes irisées)
		Muschel kalk.
	Red sandstones and conglomerates.	Bunter Sandstein. (Grés bigarré.)

Newer Palæozoic Period.

Magnesian Limestone, or Permian System.	Magnesian limestone.	Zechstein.
	Lower new red sandstone.	Shaly beds with kupferschiefer.
		Rothe-todte-liegende.
		N. B. — The Russian equivalents of this system form a beautiful and perfect series of fossiliferous rocks in the ancient kingdom of Permia, whence the name, Permian system.
Carboniferous System.	Upper coal grits.	
	Coal measures.	
	Millstone grit.	Terrain anthraxifere.
	Carboniferous limestone.	
	Lower Carboniferous shales.	
Devonian System, or Old Red Sandstone.	Slates and limestones of Devonshire.	Calcareous shales, limestones, and conglomerates of Belgium, Westphalia, &c.

Middle Palæozoic Period.

	British Rocks.	Characteristic Foreign Equivalents.
Devonian System or Old Red Sandstone.	Conglomerates, cornstones, and tilestone of Herefordshire and Scotland.	Marlstones, limestones, of a yellow and white colour, and conglomerates of Russia.

Older Palæozoic Period.

Upper Silurian Rocks.	Ludlow and Wenlock series, and Upper Cumbrian and Cambrian rocks.	Grauwacké and slaty flagstones and slates of Germany, Belgium, Brittany, &c. Clays, sandstones, &c. of Russia, both European and Asiatic.
Lower Silurian Rocks, or Protozoic Series.	Caradoc sandstone and Llandeilo flags, and older Cumbrian and Cambrian fossiliferous slates.	Shales, grauwacké sandstones, and slates, &c. of Scandinavia, and of many parts of North and South America, Africa, Australia, &c.

*** Where the name of no foreign equivalent appears, the English designation of the rocks has been adopted on the Continent, or simply translated.

GEOLOGICAL NOMENCLATURE AND DEFINITIONS.

The following short Definition of Terms, taken from the latest Authors, will be found useful in reading Works on this Subject.

AMMONITE. An extinct genus of molluscous animals, allied to the modern genus Nautilus, which inhabited a chambered shell, curved like a coiled snake. Species of it are found in all geological periods of the secondary strata, but they have not yet been seen in the tertiary beds.

AMYGDALOID. One of the forms of the Trap rocks, in which agates and simple minerals appear to be scattered like almonds in a cake.

ANTICLINAL AXIS. An imaginary line running along a ridge, the strata of whose two sides slope different ways. The ridge of a house is the anticlinal axis to the two sloping sides of the roof.

ARRAGONITE. A variety of carbonate of lime.

AUGITE. A dark green or black mineral, which enters into many varieties of volcanic rocks.

BASALT. One of the most common varieties of the Trap rocks. It is a dark green or black stone, composed of Augite and Felspar, often found in regular pillars of one or more sides, and then called "basaltic columns." The Giant's Causeway, in Ireland, is a remarkable instance of this formation.

Belemnite. An extinct species of mollusca, allied to the cuttle fish. The shell in this animal was interior, and formed the bony skeleton on which the flesh grew.

Blende. An ore compounded of the metal zinc with sulphur. It is often found in brown shining crystals.

Boulders. Large rounded blocks of stone, different in composition from the rocks in their vicinity, lying on the surface of the ground, or sometimes imbedded in loose soil.

Breccia. A rock composed of angular fragments connected together by lime or other mineral substance.

Calcareous Spar. Crystallized carbonate of lime.

Chert. A siliceous mineral, nearly allied to chalcedony and flint, but less homogeneous in texture. A gradual passage from chert to limestone (carbonate of lime) is not uncommon.

Cleavage. The direction taken by the laminæ of slate rocks which are parallel to each other, but generally not at all parallel to the original stratification, which this change frequently obliterates. This state of semi-crystallization seems to be caused or aided by weak but lengthened electric and chemical action on the mass when first deposited.*

* Professor Sedgwick is of opinion that, where slaty cleavage is unconnected with sedimentary deposition, no retreat of parts or contraction of size in passing to a

Clinkstone (Phonolite). A felspathic rock of the trap family, usually fissile: — sonorous when struck.

Conglomerate (Pudding stone). Rounded water-worn fragments of rock or pebbles, cemented together by another mineral substance, which may be either siliceous, calcareous, or argillaceous.

Comb. A valley on the declivity of a hill; generally without water.

Cornstone. A provincial name for a red limestone, forming a subordinate bed in the Old Red Sandstone group.

Crop out. A miner's term to express the rising up or exposure at the surface of a stratum or series of strata. It is also called "the basset edge."

Denudation. The removal of solid matter by marine or river currents, and the laying bare some inferior rock in consequence. This operation exerts an influence on the crust of the earth as important and universal as the deposit of sediment, and it accompanies the production of all *new* strata of mechanical origin. Fresh deposits of sediment and pebbles imply that there has been somewhere an equal grinding down of rock into rounded fragments, sand, or mud. The entire mass of stratified deposits is thus at once the monument and measure of denudation which has taken place. The erosive power of water may be seen in the hollowing out of valleys on both sides of which the same strata follow each other

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solid state can account for its origin; it must be referred to crystalline or polar forces acting together in given directions on large masses of homogeneous composition.

in a like order, and have the same mineral composition and fossil contents: where it cannot be doubted that these strata were originally continuous, and that the intervening mass which once concealed the whole series has been swept away. The most convincing evidence of denudation on a grand scale may be derived from the levelled surface of many districts with large faults:—this may be well observed in coal fields, for there the former relation of beds which have shifted their position may be exactly defined. At Ashby de-la Zouch a fault occurs, on one side of which the coal beds rise 500 feet above the corresponding beds on the other; but the uplifted strata nevertheless do not raise the face of the country, which is level; and thus the mass, which should have risen above the rest, must have been swept away. In Colebrook Dale are faults of all sizes, some of which have thrown rocks several hundred feet up or down; yet no inequality of the surface is now discernible. It is also clear that red sandstone strata, 1000 feet thick, which once covered the coal of that region, have been carried off from large areas. It is inferred in this case that water has been the denuding agent, from the fact that the rocks have yielded according to their different degrees of hardness; and the hard Trap of the Wrekin, &c. resisting more than soft shale and sandstone, now stand out in bold relief. V. Lyell's Elements of Geology.

Dip. The inclination of a stratum. The point of the compass to which it inclines is called "the point of dip:"—its degree of inclination to the horizon "the amount" or "angle of dip."

Dyke or Dike. A mass of the unstratified or igneous rocks, such as granite, trap, &c. appearing as if injected into a great rent in the stratified rocks; cutting across the strata.

Escarpment. The abrupt face of a ridge of high land, where the strata having been worn through by the action of water, their outcropping becomes visible.

Fault. A sudden interruption of the continuity of strata in the same plane, accompanied by a fissure varying in width from a mere line, to several feet, which is usually filled with broken stone, clay, &c.

Felspar. The most common ingredient in modern and ancient lava, as well as in trap, and granite rocks. It always contains some alkali:—in *common F.* the alkali is potass; in the var: called *Albite* or *Cleavelandite*, it is soda:—*compact F.* contains both. It assumes a considerable variety of forms which differ so greatly from each other as to make it difficult sometimes to recognise it. In an earthy, vitreous, or compact state, it forms the basis of all lavas, and of the greater number of trap rocks:—associated with augite, and generally in a vitreous form, it constitutes some of the well known modern basalts: mixed with hornblende it forms a large class of ancient rocks, also called basalt, when the minerals are intimately blended, or greenstone, when each is distinguishable. In a glassy but loosely aggregated state, it composes a rock of a rough, porous, and earthy aspect, called Trachyte, which is found among both ancient and modern lavas, and formations of still greater antiquity. In a compact state it is the base of many porphyries, and in a more or less crystalline form, associated with quartz, mica, and other minerals, it composes the great class of granitic rocks. As Felspar is not found in any of the aqueous sedimentary deposits except in a decomposed and regenerated state, it may therefore be considered as the most characteristic ingredient of all igneous rocks.

FLOETZ ROCKS. A term applied to the Secondary strata by the geologists of Germany.

GALENA. An ore composed of lead and sulphur.

GAULT. A term used in the West of England for a series of beds of clay and marl, the geological position of which is between the upper and lower green sand.

GNEISS. A stratified rock composed of the same materials as granite, but having usually a larger proportion of mica, and a laminated structure.

GRANITE. An unstratified igneous rock, composed of felspar, quartz, and mica.

GREENSAND. Beds of sand, sandstone, and limestone, belonging to the cretaceous period.

GREENSTONE. A variety of trap, composed of hornblende and felspar.

GREY, or GRAUWACKE. A German term usually adopted for the lowest members of the stratified rocks.

GYPSUM. Sulphate of lime.

HORNBLENDE. A dark green or black mineral, which enters largely into the composition of many trap rocks.

HORNSTONE. A siliceous mineral substance, sometimes approaching nearly to flint or common quartz.

JOINTS. Fissures or lines of parting at definite distances, and often at right angles to the planes of stratification. The partings which divide columnar basalt into prisms, are joints.

Jura Limestone. The limestones belonging to the oolitic system constitute the chief part of the mountains of the Jura. Hence that name is given to the group.

Lias. A peculiar kind of limestone, which being characterized, together with its associated beds, by peculiar fossils, forms a particular group of the secondary strata.

Lignite. Wood converted into a kind of coal.

Magnesian Limestone. A series of beds, whose geological position is immediately *above* the coal measures. It contains much magnesia.

Mica. A constituent of granite; of a shining or silvery surface, capable of being split into very thin elastic leaves or scales.

Mica Slate—Mica Schist. One of the lowest of the stratified rocks, belonging to the hypogene or primary class, containing a large proportion of mica united with quartz.

Mountain Limestone. A series of limestone strata, whose geological position is immediately *below* the coal measures, with which they sometimes alternate. They are distinguished from the older limestone formations by the abundance of shells and corals which they contain.

Muschelkalk. Shell limestone. It belongs to the red sandstone group in geological position.

Nummulite. An extinct genus of mollusca; of a thin lenticular shape, internally divided into small chambers.

Obsidian. A volcanic product or species of lava very like common bottle glass; black in large masses; semi-transparent in thin fragments. Pumice stone is obsidian in a frothy state, produced most probably by water that was contained in or had access to the melted stone, and which was converted into steam. There are often portions in masses of solid obsidian which are partially converted into pumice.

Oolite. A limestone, so called because it is compounded of rounded fragments, like the roe, or eggs of a fish.

Outlier. A portion of a stratum, detached, and occurring at some distance from the general mass of the formation to which it belongs.

Plastic Clay. One of the beds of the Eocene period, so called from its use in making pottery. The formation so named is a series of beds, chiefly sand, with which clay is associated.

Porphyry. An unstratified, igneous rock. The name was first applied to a red rock with small crystals of white felspar diffused through it, brought from Egypt. It is now applied to every species of unstratified rock in which detached crystals of felspar or some other mineral are diffused through a base of other mineral composition.

Quartz. Pure silex. Rock crystal is quartz.

Ripple Marks. These marks which are seen on sea shore sands at low tides, occur also on sandstone strata of all ages, and are considered as a proof that these strata have been formed under the sea. Ripple is not confined to sands affected by tides, but is produced also on those constantly covered by water, from the action of contrary currents. Two fluids of different specific gravity will form ripple by the lighter passing over the other, and the lines of ripple marks are always at right angles to those of the current that forms them. Instances are found of two sets of ripples, one having formed over the other from a change of current. Marks of drops of rain may also be seen on old sandstone, and from their slanting direction it may be inferred which way the wind blew at the time. The preservation of those fossil marks, as well as of the footsteps of birds and animals, often found in *new* red sandstone, is owing to the hollow impressions on the wet sand having been covered, before they were obliterated by any more violent action,—with a thin coat of mud or marl; another layer of sand formed above that, and in after ages, when the soft sands became hard stone, and were elevated as dry land, they split open at the layer of different materials and showed the casts thus preserved.

Rock, is a term applied equally to all mineral substances, soft and hard. Clay, sand, and even peat are included.

Rocks (aqueous), also called sedimentary or fossiliferous. They are supposed to have been formed by depositions from water, and cover more of the earth's surface than any other. They are stratified, and contain numerous organic remains. The process by which such strata have been formed may be seen even now in the deposits left by the Nile, where each layer differs in colour from the stratum above it, and is easily separated from it. Beds of sand, clay, and marl, containing shells, pebbles, and animal and vegetable remains are found arranged in the same manner in the interior of the earth, and have an aqueous origin, as shewn by the pebbles rounded by the action of water, the immense number of marine shells, and the remains of animals, chiefly aquatic, which are found among all stratified rocks. They abound in some stones so much as to form the entire mass, and that called Nummulitic, is composed of chambered shells of the class cephalopoda of the most minute and exquisite construction. In the Tripoli polishing stone the siliceous shells which entirely constitute it are so minute that the microscope shows 500,000,000 contained in a cube of $\frac{1}{10}$th of an inch.

Rocks (metamorphic), so called from the supposed change of structure they have undergone in consequence of their vicinity to some heated mass which has brought the parts contiguous to it into a state of semi-fusion, and thus obliterated all organic remains, and given a crystalline structure to the mass. The metamorphic rocks consist of Gneiss, Mica Schist, Clay Slate, Dolorite Schist, Marble, and the like. They contain no pebbles, ore, sand, &c.; but, notwithstanding their crystalline structure, are divided into strata like sedimentary formations. Instances may be seen where the insertion of an igneous rock has changed a dark limestone full of shells and corals, through which it forced its way, into white marble in the parts nearest to the fiery mass.

Rocks (plutonic), are supposed to be of igneous origin. This division comprehends all the granites and some porphyries. They are thought to have been formed from a fused mass, cooled and crystallized by slow degrees, at great depths in the earth, and under enormous pressure. They differ from volcanic rocks by a more crystalline texture, and by the absence of all tuffs and breccias (products of the earth's surface) and also by wanting those cellular cavities which arise in common lava from the expansion of entangled gases. Granite frequently *pierces through* strata, but rarely *rests on* them, as if from overflow, which is the peculiarity of volcanic rocks, hence called by Mr. M'Culloch, *overlying*.

Rocks (volcanic), are the produce of subterranean heat; are mostly unstratified and devoid of fossils. The most remarkable of those in Europe are those of Italy and Sicily, part of Germany, Iceland, and Central France. They are of two kinds, i.e. the submarine and those formed under no pressure but that of the atmosphere. The first comprehend all the British Trap rocks.

Sandstone (Old red). A stratified rock lying below the carboniferous group.

Sandstone (New red). A series of sandy argillaceous and often calcareous strata, whose predominant colour is brick red, but containing portions which are of a greenish grey.

Schist. A mineral capable of being split in the manner of slate, but not so thoroughly.

Selenite. Crystallized sulphate of lime.

Serpentine. A rock usually containing much magnesian earth; for the most part unstratified, but sometimes appearing to be an altered or metamorphic stratified rock.

Shale. An indurated slaty clay.

Silex. Flint.

Stratum. A bed, or layer, of earth or rock. Strata lying together in regular order, with planes parallel to each other, are said to be "conformable," but they may have any inclination to the horizon. When one series is placed over another, so that the planes of the upper rest upon the edges of the lower, they are called "unconformable." A period has in this case elapsed between the production of the two sets of strata, during which the lower series has been disturbed and tilted. If the upper beds are inclined also, the lower must have been twice displaced, i. e. when they were first inclined themselves, and a second time when the upper beds were thrown out of their level also.

Strike. The direction of the ridge or valley caused by the dip of strata which is always at right angles to the dip. Thus if the strata dip is from E. to W. the strike is from S. to N.

Syenite. A kind of granite. To mark the distinction between Old and New Granite, the word Syenite has been used for all granitic rocks which have been intruded through the palæozoic, as well as through the young or sedimentary strata.

Talus. When fragments are broken off by the action of the weather from the face of a steep rock, as they accumulate at its foot, they form a sloping heap called a "talus."

Trachyte. A variety of lava essentially composed of glassy felspar, and frequently having detached crystals of felspar in the base or body of the stone, giving it the structure of porphyry. It sometimes contains hornblende and augite, and when these last predominate the trachyte passes into the varieties of of Trap called Greenstone, &c.

TRANSITION. A term originally used by Werner, to describe a mineral formation intermediate between the crystalline and the common fossiliferous rocks.

TRAP. Volcanic rocks composed of felspar, augite, and hornblende. The various proportions and state of aggregation of these give rise to varieties with distinct appellations, as basalt, amygdaloid, dolorite and others.

TRAVERTIN. A concretionary limestone usually hard and semi-crystalline, deposited from the water of springs holding lime in solution. It is called Calc Sinter by the Germans.

TUFA. Lighter Travertin.

WACKE. A rock nearly allied to basalt.

ZEOLITE. A family of simple minerals, including stilbite, mesotype, analcime, and some others usually formed in the trap or volcanic rocks. Some of the most common swell or boil up when exposed to the blowpipe. Hence the name, from ζεω to boil.

SKETCHES OF GEOLOGY.

CHAPTER I.

Introduction.

AMONG all the vast subjects for study and contemplation which Nature presents, few are more deeply interesting than the science of Geology. Man stands on this globe surrounded by proofs of the Infinite Wisdom, Power, and Goodness of his Almighty Maker:—he looks up to heaven, and exclaims 'Thou art there!' and down to earth to repeat, 'Thou art there also!'—he feels himself placed in a world of wonders, whose ceaseless revolutions are rapidly whirling him round the circle of time, till he drops from it into the vast abyss of eternity; and he desires to gain a knowledge of his kindred earth, and to trace the history of that soil, alike his cradle, his home, and his grave. A great poet, who says,

"All are but parts of one stupendous whole,
Whose body nature is, and God the soul,"—

has thus perhaps more finely expressed the relation which the Supreme Being bears to his works, than has ever been done by any other writer; and the farther we pursue the study of Nature, the more deeply will it impress on our minds, that one Great First Cause animates the Universe; "lives through all life; extends through all extent."

The farther we advance in knowledge, the more we shall discover and admire the simplicity of those primary rules called "Laws of Nature," by which the Divine Author of the whole governs and regulates all its operations. The truths of Natural Religion are indelibly impressed by an Almighty hand on every fragment of this material world, and from the summit of its highest mountains, to the depth of its lowest caves, every layer of rock that forms them is an altar of unhewn stone, on which these truths are written by the finger of God.

The writer of the present work, in common with the authors of the other "Small Books," is an earnest advocate for the advance of truth on all subjects; and feels that all who endeavour to co-operate in that sacred cause, have put on "the armour of light," and that its radiance, shed on their path, will clear up and disperse all mists of doubt and difficulty that might otherwise arise to darken their way. A master mind * has acknowledged that we must wade through error in our progress towards truth; but when it is once reached through such a course it will be irresistible, and will calm the weak fears of prejudice, and defy the attacks of unreasonable scepticism. Some minds indeed possess beyond others an intuition into the true bearing of facts on any question, but statements made on evidence which cannot be disproved, *will* sink into the minds of all who hear them, listen in what mood they may.

The science of geology in its first dawn, and through all its early stages, was obscured by errors, and confused at every step by a host of mistaken theories: within the last few years, however, modern geologists, by the most untiring exertions, have personally explored nearly all the civilized, and some of the uncivilized regions of the globe; and proved the existence of the facts on which they found their views.

* Lord Bacon.

The conclusions drawn from these discoveries and labours, are supported by the records of past ages traced in language more imperishable than that of any known human transactions. The relics of beings entombed in the strata heaped by myriads of ages on their graves, give a present and tangible evidence of their past existence which no human testimony can compete with; and prove that the changes of our globe, since it has been the abode of man, are but as a page in the massive volumes of its history.

The records and traditions of ancient nations as far as we are acquainted with them, are filled with accounts of great convulsions of nature, followed by a new state of things, which probably were the dim recollections of some of those changes whose traces are still to be found in the present crust of the earth: but they are too vague to be much dwelt upon,* and the Greeks are the first who seem to have argued from *facts*, that such changes must have taken place. Xenophanes, who flourished about 600 B. C. is the first who is distinctly asserted to

* Those who wish to see the whole of the ancient traditions of this kind brought into one point of view, will find the subject amply treated in the first chapters of Lyell's Principles of Geology.

have grounded his opinion that what is now solid earth must once have been sea, on the facts that sea shells are found in it even on the tops of mountains—that in the quarries of Syracuse remains of fishes and phocæ exist in the stone, and in those of Paros, apuæ, a sort of fish found mainly on the coast of Athens, are embedded in blocks of solid marble.*

This was a rational and intelligible argument; and accordingly Xenophanes may justly be placed at the head of practical geologists. The theory he grounded on these facts was, that the earth had been destroyed and re-formed many times, and that whilst these convulsions were going on, men must necessarily have been destroyed, and the race would require a fresh beginning.

But the world was not then enough advanced in the means of preserving knowledge for the use of posterity, to allow this promising germ to fructify. The opinions of Xenophanes were recorded as a matter of curious speculation, but for above 2000 years none attempted to found scientific conclusions on these facts. *Printed* books may yet be found asserting that the ap-

* Orig. as quoted by Brucker, Hist. Crit. Philosophiæ.

pearances of shells and bones in a fossil state were mere *lusus naturæ;* and their real origin was scarcely acknowledged till the last century, although a few rational observers travelled in advance of their age, and ventured to brave the ignorant clamour of their contemporaries. Among these may be mentioned,

Fracastoro, 1517, who declared his opinion that the fossil marine shells found in excavations at Verona, had all belonged to living animals.

Cardano, 1552, when treating of petrified shells in his work "*De subtilitate*," decided that they indicated the former sojourn of the sea upon the mountains.

Palissy, 1580. "He was the first," says Fontenelle in his eulogy, "who dared assert," in Paris, "that fossil remains of testacea and fish had once belonged to marine animals."*

Fabio Colonna, 1626, had the merit of being the first to point out that some of the fossils had belonged to marine, and some to terrestrial testacea.

Steno, 1669, the professor of anatomy at Padua. In order to disprove the opinion that fossil bones, &c. were not of animal origin, he

* Lyell's Princip. of Geol. vol. i. p. 38.

dissected a shark recently taken from the Mediterranean, and demonstrated that its teeth and bones were identical with many fossils found in Tuscany. He had also compared the shells discovered in the Italian strata, with living species, pointed out their resemblance, and traced the various gradations from shells merely calcined, or which had only lost their animal gluten, to those petrifactions in which there was a perfect substitution of stony matter. He declared that he had obtained proof that Tuscany must successively have acquired six distinct configurations, having been twice covered by water, twice laid dry with a level, and twice with an irregular and uneven surface.

Leibnitz, the great mathematician, published his "Protogæa" 1680. He imagined this planet to have been originally a burning luminous mass, which ever since its creation has been undergoing refrigeration. When the outer crust had cooled down sufficiently to allow the vapours to be condensed, they fell, and formed an universal ocean, covering the loftiest mountains, and investing the whole globe. The crust, as it consolidated from a state of fusion, assumed a vesicular and cavernous structure; and, being rent in some places, allowed the water to rush into the subterraneous hollows, whereby the level of the primæval ocean was lowered. The waters after they had been thus agitated, deposited their sedimentary matter during intervals of quiescence. "We may recognise, therefore," says he, "a double origin of primitive masses; the one by refrigeration from igneous fusion; the other by concretion from aqueous solution."

Hooke, 1688, *Ray*, 1692, *Woodward*, 1695, wrote on fossil remains, and the subject now became one of more general interest. *Burnet*, 1690, and *Whiston*, 1695, published their visionary theories, and so far gave the tone to succeeding writers, that the chief part of the eighteenth century was distinguished more by the ingenious hypotheses than the sound views of writers on geology in Germany and England: in Italy, *Generelli*, 1749, was the advocate of a more practical view; and he was well seconded by many of his countrymen.

It was in 1775 that *Werner* was appointed professor of mineralogy in the school of Mines, at Freyberg in Saxony. He directed his attention, not merely to the composition and external characters of minerals, but also to what he termed the "geognosy," or natural position of minerals in particular rocks, together with the grouping of those rocks, their geographical relation, &c. The phænomena observed in the structure of the globe had hitherto served for little else than to furnish interesting topics for philosophical discussion; but when Werner pointed out their application to the practical purposes of mining, they were instantly regarded by a large class of men as an essential part of their professional education, and from that time the science was cultivated in Europe more ardently and systematically than it had before been.

The principal merit of Werner's system of instruction consisted in steadily directing the attention of his scholars to the constant relations of superposition in certain mineral groups: but he had been anticipated in the discovery of this general law by several geologists of Italy and elsewhere; and his leading divisions of the secondary strata were at the same time, and independently, made the basis of an arrangement of the British strata by our countryman, William Smith.

Werner's hypothesis with regard to the formation of the different strata was, that all were aqueous deposits, either in the natural course of subsidence, or by chemical crystallization. Subsequent examination has proved this to be erroneous; but for a time "the aqueous theory," as it was called, had warm partisans. Shortly after, however, a closer inspection of volcanic products induced many continental geologists to take a different view; and in 1788, Dr. Hutton, in England, published a "Theory of the Earth," in which he took the side opposed to Werner. "The ruins of an older world," said he, "are visible on the present structure of our planet; and the strata which now compose our continents have been once beneath the sea, and were formed out of the waste of præ-existing continents. The same forces are still destroying, by chemical decomposition or mechanical violence, even the hardest rocks, and transporting the materials to the sea, where they are spread out, and form strata analogous to those of more ancient date. Although loosely deposited along the bottom of the ocean, they become afterwards altered and consolidated by volcanic heat, and then heaved up, fractured, and contorted." He demonstrated by various arguments and experiments which subsequent knowledge has confirmed, that basalt and other trap-rocks were of igneous origin; and he formed the same opinion with regard to granite; this too has been adopted by later geologists as the true one.

The "Aqueous" or "Neptunian," and the "Igneous" or "Vulcanic" theories were now at open war, and the combatants on either side were as warm in their partisanship as men are wont to be when they think great truths are at stake; till, at last, weary of this unbecoming heat in matters where nothing but calm discussion can elicit the truth, the scientific world began to discourage theories, and to seek for facts. In 1807 the Geological Society of London was instituted, and in 1808 the first step was made in that path which has since proved so fruitful in scientific truth by Messrs. Cuvier and Brongniart's publication of their work, "On the Mineral Geography and Organic Remains of the Neighbourhood of Paris."

The labours of Cuvier may be said to have laid the foundation of the science, for he dealt with *facts;* and after having pointed out the path for future geologists, he calmly bade them await the time when the accumulation of farther facts would enable them to build up a science upon the only true grounds. Before his time the theories of Werner had been, for the most part, received in France as a sufficient explanation of the phænomena of the earth's crust: Cuvier first applied the science of comparative anatomy, of which he was perfect master, to the elucidation of these phænomena. "When the sight of some bones of the bear and elephant, twelve years ago, inspired me with the idea of applying the general laws of comparative anatomy to the reconstruction and the discovery of fossil species,"—observes he, with an honest exultation in the greatness of the service he had rendered to science,—"I did not suspect that I was destined to bring to light whole genera of animals unknown to the present world, and buried for incalculable ages at vast depths under the earth. It was to M. Veurin that I owe the first indications of the bones furnished by our quarries: some fragments, which he brought me one day, having struck me with astonishment, I made inquiries for such bones in all the quarries; and offering rewards to arouse the attention of the workmen, I collected a greater number than any person who had preceded me. After some years I was sufficiently rich in materials to have nothing further to desire; but it was otherwise with respect to the arrangement and the construction of the skeletons, which alone could conduct me to a just knowledge of the species. From the first moment I perceived that there were many different species in our quarries;

and soon afterwards that they belonged to various genera, and that the species of the different genera were often of the same size; so that the size rather confused than assisted my arrangement. I was in the situation of a man who had given to him, *pêle-mêle*, the mutilated and incomplete fragments of a hundred skeletons, belonging to twenty sorts of animals, and it was required that each bone should be joined to that which it belonged to. It was a resurrection in miniature, but the immutable laws prescribed to living beings were my directors. At the voice of comparative anatomy, each bone, each fragment regained its place. I have no expressions to describe the pleasure I experienced in perceiving that, as I discovered one character, all the consequences, more or less foreseen, of this character, were successively developed. The feet were conformable to what the teeth had announced, and the teeth to the feet; the bones of the legs and thighs, and every thing that ought to reunite these two extremes, were conformable to each other,"—and he farther explains this by adding, " Every organized being forms an entire system, of which all the parts mutually correspond and co-operate, to produce the same action by a reciprocal re-action; none of these parts can change without a change of the others also. Thus, if the intestines of an animal be organized in a manner only to digest fresh flesh, it is necessary that his jaws should be constructed to devour the prey, his claws to seize and tear it, his teeth to divide the flesh, and the whole system of his organs of motion to follow and overtake it, and of his organs of sense to perceive it at a distance."

It was very soon apparent that the animals thus reconstructed from the fragments of their bones, belonged to different strata; further examination showed a gradation in animal life, from the crystalline rocks where no fossil remains are found, to those where the lowest organisms shew themselves; and so on, through the various classes, to the later strata where the mammiferæ first make their appearance. Here was at once a guiding light:—it only required a farther accumulation of facts, to determine whether the rules to be derived from this observation were constant;—if they were, *the* SCIENCE *was founded;* and nothing more was needed than longer, and more extended observations. But the great mind of Cuvier was not deceived: the observations of facts which he had insisted on as the only true foundation of science, were now rapidly made and reported; and all tended to show that he had read nature with an almost prophetic eye. Geologists abandoned their theories;—in France, in England, in Germany, fossil remains were examined and classified; and no step was now made unsupported by the rational testimony thus afforded. In this small space it is not possible to do more than just name a few of the most distinguished labourers in this fruitful field.

Contemporary with Cuvier was the so-called "Father of English Geology," William Smith, to whom belongs the honour of one of the greatest discoveries in this science, which Professor Sedgwick has described as its master principle; i. e. that each System of Strata has its own peculiar species of fossil remains; so that these, and its mineral formation, are reciprocally characteristic. His "Tabular View of the British Strata," his classification of the secondary formations, with his "Geological Map of England,"—the first of the kind, will remain a lasting memorial of his talents and his labours.

Lyell, who has been acknowledged "facile princeps" among geological writers, turned his attention mainly to the more recent formations, and has marked a fresh step in the science by pointing out the importance of the fossil remains of testacea in determining the age of strata. "They are," he observes, "the medals which nature has chiefly selected to record the history of the former changes of this globe, for," he adds, "there is scarcely any great series of strata that does not contain some marine or fresh water shells;"—and these are often found so perfect that their classification is easy. They have also a wide geographical range, and each genus has a duration for the most part superior to other classes of animals; so that a wider spread of surface and a longer period may thus be brought into one class. His division of the Tertiary period into the Eocene, Meiocene, and Pleiocene series* has been universally adopted.

But of all the host of earth's scientific conquerors, the most recent and the greatest re-

* Namely, the early, the less, and the more—alluding to the quantity of shells of recent species to be found in them. "It appears," he says, "that the numerical proportion of recent to extinct species of fossil shells in the different Tertiary periods may be thus expressed. In the

Newer Pleiocene period about	90 to 95	per cent. of recent fossils.
Older	35 to 50	
Meiocene period . .	17	
Eocene period . . .	$3\frac{1}{2}$	

mains to be mentioned. The gigantic labours of Sir Roderic Impey Murchison, and the years he has spent in exploring alike the ancient rocks, once the stronghold of the aboriginal Britons, the mountains of Scandinavia, and the vast plains of Russia, have resulted in the establishment of a system unknown to the science before, and have added to the tablets of stone those lines which till now had been wanting to the record. He has deciphered the characters written by the hand of nature on the most ancient rocks, traced upwards the order of a regular succession, and given full proof of the correctness and truth of his views by the evidence of observed facts.

Space will not allow more than the mere mention of the names of Greenough,* Buckland,

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* This gentleman's Geological Map of England, and various other labours, were early and important services rendered to the Science, but not the only ones for which it is deeply indebted to him. Mr. Greenough was the first President of the Geological Society, and mainly instrumental in its formation. It may interest the reader to learn the origin of that now flourishing and important Association, which, like many other great results, may be traced to a small and humble beginning. About 40 years since, a few gentlemen used to meet in the late amiable and excellent Dr. Babington's Laboratory,

Phillips, Conybeare, Delabeche, Darwin, Edw. Forbes, &c. &c., but it may be said of all, that they have written from personal observation: that their field of labour lay in the quarry and the mine, on the cliff and the mountain, beneath the ocean and the lake. The facts of the science have been sought for, found, and proved, by every means of research and demonstration within the reach of human powers; and all that follow must advance by the same path, and by the same efforts; for such alone will ensure success, or be rewarded by the discovery of truth.

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in Aldermanbury, for the purpose of discussing various philosophical subjects, especially Chemistry, Mineralogy, and Geology. Among those who formed that little scientific band of friends, were Dr. Babington, Sir Humphry (then Mr.) Davy, Messrs. Wm. Allen, Pepys, Richard and William Phillips, Woods, Children, Dr. Laird, Arthur Aikin, Count de Bournon, and Greenough, with some others, whose names have escaped the septuagenarian recollection of the writer of this note. The great event in which these meetings terminated was the founding of the Geological Society, which at first met at the Freemason's Tavern, Great Queen Street, and as already stated, Mr. Greenough, was chosen its first President. After dinner, original Geological papers were read, and commented on, by the members present, and the earliest contributions to the Transactions of the Geological Society, those, namely, by the late Dr. Macculloch, were thus first given to the world.

Here then stands Geology at present. Not as complete, but as now travelling onwards with assured steps, and increasing certainty, towards the solution of one part of that great problem of Existence which is in fact the object of all science: for science is but knowledge, and our attainment of it depends on the restless feeling which developes itself in us the moment our senses are capable of receiving an impression, and demands incessantly, What are these objects about us? What are we ourselves? Where are we to find the Author of existence? and what is the object of all? The endeavour to answer these questions is the noblest, and probably the destined employ of the human intellect. Let us therefore beware how we attempt to discourage the inquiry after truth, wherever it may be traced, "lest," to use the words of Gamaliel on a greater occasion, "haply we be found to fight against God."

CHAPTER II.

The Earth's Crust.

THE first thing which strikes the eye of the observer who travels over a mountain road, will be the fact that various strata, or beds of earth and rock, differing in appearance and qualities, lie over and beside each other in every variety of position; now horizontal, now sloping, now vertical. He will see farther, in some deep cutting, that a bed of rounded gravel which must have owed that form to the violent action of water in commotion, is surmounted by a deep bed of clay, or earth of some kind, in a horizontal position, showing a quiet deposition from muddy water for a length of time: another bed of rounded gravel will succeed to this, and again, over the gravel will be found beds of earth or sand.

We will suppose our traveller absolutely ignorant of geology or mineralogy; yet if he have but a commonly cultivated mind, he will see that here are facts which must have a meaning; and that strange convulsions of the earth's crust must have occasioned appearances which tell of such varying conditions of its surface. The traveller we have imagined has made now the first step in geology. He has seen facts not to be gainsaid, and reads in those two beds of gravel the history of many centuries. The first thought on the subject is awakened. He seeks further facts, and he accounts for them on grounds which all must acknowledge; for hard stones cannot be thus rounded without being long tossed over each other by water; and the mud which settled above them must have had time to acquire an almost stony hardness, ere the water which produced the second bed of gravel, could have washed so violently to and fro upon its surface without disturbing it. I have given this argument at greater length than so simple a fact seems to deserve, because it is desirable to show how certain the conclusions are, which on many occasions may be drawn from natural appearances.

The form of the earth,—an oblate spheroid,—gives fair room to conclude that when it first began its revolution it was at least a semifluid mass; and the evident igneous origin of so large a portion of its rocks, added to the regular increment of temperature keeping pace with the depth, in mines, has led most of our later geologists to adopt the opinion that the interior of this globe is still in a state of fusion; and that, like the fresh lava of a volcano, it has only a certain portion of solid matter spread over its surface. This, however, is a point on which it is clear that no decided certainty can be attained; for that part of the crust of the earth which is accessible to our observation, and which consequently we can reason upon, comprehends not more than about ten miles, or $\frac{1}{400}$ of the distance from the surface to the centre; and even this knowledge is only gained from the upturning of different strata, either in a forced elevation, or subsequent subsidence, so that the edges crop out, and enable us to measure their actual depth on the surface of the earth. The deepest mine does not much exceed half a mile of downward progress, therefore the knowledge to be gained by actual excavation, supposing the strata always to have remained in a horizontal position, would have been but small.

This, however, has not been the case: every part of the earth's surface presents evidence of violent dislocations;—of denudation from above by the action of water and air; of upheaving and subsidence* consequent on causes acting in the interior; and it is upon these abraded or contorted strata that the geologist has to reason, and ascertain, by the fossil contents there imbedded, as well as by the mineral structure, what was the age of that formation.

Nothing has as yet been found below the crystalline rocks, which, according to all appearance,

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* "In the neighbourhood of Puzzuoli there are abundant marks of alternate rise, and subsidence; but the temple of Serapis affords the most curious instance. The platform of the temple is at present about one foot below high water mark; the pillars have been each carved out of a single block of marble, and are 42 feet in height. A horizontal fissure nearly intersects one of the columns, the other two are entire. They are all slightly out of the perpendicular inclining towards the sea. Their surface is smooth and uninjured to the height of about twelve feet above their pedestals. Above this is a zone about nine feet in height, where the marble has been pierced by a species of marine perforating bivalve (*Lithodomus*, Cuv.). The perforations are so considerable in depth and size that they manifest a long continued abode of the lithodomi in the columns; we must consequently infer a long-continued immersion of the pillars in sea water, at a time when the lower part was covered up and protected by strata of tuff, and the rubbish of buildings, the highest part at the same time projecting above the waters." See Lyell's Principles of Geol. Vol. 2, p. 312, et seq.

are the result of the first cooling down of the fused mass: upon these rest sedimentary strata which must have been deposited from water, and in which the first and lowest forms of organized beings become visible. Frequently, as in Sweden and Norway, the crystalline rocks are thrown up into mountains, and the more ancient sedimentary strata rest in basins, as it were, among them: at other times the crystalline rocks have remained *in situ* till sedimentary strata were deposited upon them; and then by a sudden force acting from beneath, the whole has been forced upwards at a particular point, elevating the crystalline ground work with its superimposed strata;* and then again, the action of air and water has denuded the upper part of the harder rock, and left only some highly inclined strata towards the base. The substance thus washed down into the valleys, will again form horizontal strata, until these too are upheaved; and then the like operation is repeated. This is no imaginary picture: it is to be observed in the position and contents of these strata as plainly as in the beds of gravel above mentioned.

* See Murchison's Geol. of Russia, Vol. 1, p. 17.

Such was the state of things which forced itself on the observation of those who looked at nature with more than a superficial glance: and as it was evident that the different kinds of fossils imbedded in the strata required different conditions of the surface of the earth for their support; geologists have of late divided the periods during which these conditions prevailed into three.

1. The Palæozoic or ancient period, where the earliest organic remains of kinds now extinct, and chiefly belonging to invertebrate animals are found.
2. The Secondary, where remains of vertebrata of the class of reptiles abound.
3. The Tertiary, in which the bones of quadrupeds of the class Mammalia chiefly occur.

These periods, it is supposed, had all elapsed previous to the creation of man; for no human remains have yet been discovered among the millions of once living organisms found imbedded in the rocks then formed.

The next business was to classify the strata of each period, so as to facilitate the consideration of the subject; and here, as the sedimentary strata must have been formed under water, the shells found in them were generally the surest mark of their age and relations; upon these, therefore, since Lyell pointed out their use, the classification has mainly been founded. When sets of strata, evidently sedimentary, are found to contain shells of the same species, or a large proportion at least of the same species, it is concluded that these depositions have taken place during a season of comparative quiet, and that the difference of mineral composition is mainly the result of a difference in the substances which may have been brought down by rivers, &c. into the ocean, under which they were formed: and these strata, which generally rest conformably on each other, are termed *systems*. Thus we have the Silurian, the Devonian, the Carboniferous, the Permian systems, making up, as a whole, the Palæozoic period. Each of these systems exhibits a change in the fossils, and sometimes the whole series of strata composing one system have undergone an upheaval, or disturbance, which the next in order bears no trace of: thus affording proof that, after the convulsion which effected the disturbance, a fresh period of quiet deposition had occurred, again to be interrupted, and again renewed.

Sir Roderick Murchison, in his late splendid work on the Geology of Russia in Europe, has distinguished the rocks which composed the ancient crust of the earth as AZOIC or non fossiliferous, in contradistinction to the Palæozoic; and as this classification is founded on facts rather than theories, it is here adopted. "We apply the term *azoic*," he observes, "to the crystalline masses which preceded that palæozoic succession to which our researches were mostly directed; not meaning thereby dogmatically to affirm that nothing organic could then have been in existence, but simply as expressing the fact, that in as far as human researches have reached, no vestiges of living things have been found in them; so also from their nature they seem to have been formed under such accompanying conditions of intense heat and fusion, that it is hopeless to expect to find in them any traces of organization. In the term "Azoic rocks," are included all the crystalline masses belonging to the ancient group of Gneiss, together with the ancient granitic and plutonic rocks by which they have been invaded." And here, in strictness, should be added all those rocks of any age whose structure shows them to have become hardened or crystallized from a state of fusion: but, of these, many are comparatively of recent origin; nay, up to the present day, lava currents are formed which are necessarily azoic, so that this circumstance *alone* cannot fix the age of any formation.

Of all the Azoic rocks the Granitic are the most abundant: they form the highest peaks, and the nuclei round which altered and stratified rocks are collected in all the principal mountains. Their structure is crystalline, and they bear strong marks of having cooled slowly from a state of intense heat. They are found in all parts of the globe, often in very extensive masses. In Britain they occur in Cornwall, Wales, and Scotland: in the continent of Europe, in the Scandinavian and Hartz mountains, in the Alps, Pyrennees, and Carpathian chain: in Asia they form the centre of the Caucasus, and occupy a great part of the Ural, Altai, and Himalaya mountains, and are also found in Siberia. They appear in Africa, in Upper Egypt, in the Atlas, and at the Cape of Good Hope: are traceable all down the western coast of both Americas, and appear again in the islands of the Pacific, and in Australia. From this great extension, granite might be considered the solid frame-work of the globe; and, under this persuasion, it was for a time termed a primary rock; but closer observation has shown that it has sometimes been injected among other rocks in a paste-like or fluid state, long after the Azoic period; therefore, though it is generally the oldest rock, it may also be formed and extruded from the fused mass supposed to exist within the globe, at any period.

Next in succession to the crystalline rocks, and with nearly as wide an extension, come those called Gneiss, Mica Schist, and Clay Slate. They are often to a certain degree crystalline, but bear also marks of having been deposited from water. No distinct order of superposition can be assigned to them. If granite be pounded, and thrown into water, it will deposit itself at the bottom, in a state similar to that of Gneiss, which is merely granite stratified.* Its materials are the same as those of granite, but their proportions differ, the mica being more, and the felspar less abundant: its planes of stratification are nearly parallel to each other, and sometimes to the surface of the granite it rests on: at other times there is a gradual transition from the igneous to the altered rock; which latter loses its distinctive character of stratification at

* Ansted's Ancient World, p. 18. Ib. p. 19.

its junction with the granite, and the one passes into the other almost imperceptibly.

Mica Schist is the rock next in extent to Gneiss of this metamorphic class; it is slaty, and composed of mica and quartz,—mica predominating. Beds of pure quartz occur in this rock, and garnets in regular twelve sided crystals are also found. It passes by insensible gradations into Clay Slate, otherwise called Argillaceous Schist. This last rock is common to both the metamorphic and fossiliferous series: it resembles indurated clay, and contains a large proportion of argillaceous matter, mixed with a still larger of silica, a little iron, and some of the alkaline earths.

The above three rocks surround and overlie the granite in abundance, " as if they had been formed from its broken and rough edges, worn away by the waters of the first ocean, and afterwards deposited at the bottom." Slate rocks have a regular *cleavage* quite distinct from their strata; and this formation is remarkable for the uniformity of its direction through a great extent of country. This is shown on a large scale in North Wales, where the whole region is made up of contorted strata, but whether straight or curved, all the beds have undergone the same change; and it appears that electric or magnetic forces, acting simultaneously on the whole mass, in given directions, had past alike through all the strata, and produced in them a like cleavage. These peculiarities of structure are far more frequent in the Azoic rocks than in any of those which are fossiliferous as well as stratified; and give reason to suppose that electric currents were generated by heat, which afterwards left the refrigerated strata fixed in the state they now exhibit.

All the older rocks, and many of the new, have had rents or fissures opened in them by a force acting from below; and these have been filled up by melted matter which has often been thrown out at the surface, and spread out in broad masses. These are called basaltic and trap-rocks; and in their manner of occurrence, and mineral structure, are strictly analogous to the lava poured out by modern volcanoes. The minerals which come in contact with basaltic veins of this kind undergo great changes; limestone is altered into crystalline marble, sandstone into quartz, and slate or shale into claystone, and the rocks thus altered at their point of junction with the basalt, will be seen less and less changed as they recede from the injected matter.

Lava when first thrown out appears in the form of a semifluid mass, intensely heated; and its appearance as a mineral mainly depends on the circumstances of its cooling. In the open air it is cellular, and resembles a mass of loose ashes; cooled slowly, under pressure, it is hard and massive, and shows signs of prismatic structure. It often encloses crystals, and its structure is vesicular. Its mineral composition varies, but felspar is always the base, mixed with iron and alkaline earths. The identity of basalt with lava has been so satisfactorily proved by an experiment conducted by Mr. Gregory Watt,* that I shall here abridge it for the benefit of those who may not have the books at hand. The experiment was made on a mass of Staffordshire basaltic rock, weighing seven hundred weight, which was subjected to the heat of a reverberatory furnace: it melted at a less heat than is required by iron, and took the appearance of liquid glass. Some of this was taken out and allowed to cool; but even then it retained the appearance of a glass. The part left in the furnace was not removed for eight days, when, though cool externally, it retained a good deal of

* See Phil. Trans. for 1804.

heat internally; and upon examination exhibited many of the peculiarities belonging to bodies passing from a vitreous to a stony state. First it resembled obsidian, then varieties of jasper, afterwards advanced towards a stony texture, showing some tendency to a columnar structure. In the next change it became more granular, the colour changed from black to grey, and the mass became pervaded with crystalline laminæ, apparently the consequence of a commencement of polarity. Crystals were next projected from the cavities, and the mass became porphyritic, and ultimately a mass of crystals.

CHAPTER III.

Ancient or Palæozoic Period.

§ A.

Silurian System.

FOR a considerable time geologists entertained but vague notions of the strata which intervened between the igneous and crystallized rocks, just described under the title of Azoic, and the decidedly fossiliferous ones known at that time by the name of "old Red Sandstone." All between that and the crystalline rocks was termed "Transition," or, more vaguely yet, "Grauwacké,"—and no one had succeeded in giving any regular arrangement of the strata thus characterized. It was therefore like the dawn of a new æra in science, when Sir Roderick, then Mr. Murchison, announced to the world that he had discovered a regular *system* of strata, lying beneath the old red sand stone, and above the old crystallized and plutonic rocks.

It was in Wales, in that part of it formerly inhabited by the Silures, that these strata were found to exhibit themselves most characteristically; and though they have since been found diffused very widely in Scandinavia, Russia, North America, and other parts, yet the name Silurian has been adopted by geologists for this system: for it has the especial advantage of asserting no theory which subsequent discoveries might upset, but merely records the fact, that in that region such strata exist. Thus, as William Smith named the Oolitic British rocks from those places where their age and sequence is best proved by order of position and organic remains, so Murchison calls the Silurian rocks (according to the ascending order which is now most generally adopted), the Llandeilo, Caradoc, Wenlock, and Ludlow formations. The two first he names the Lower, the two last, the Upper Silurian rocks. They are of immense thickness, and each subdivision has its characteristic fossils; though enough of the same genera run through the whole to mark it as *a system.* The following table will show the arrangement, mineral characters, and fossil remains of these strata.

		Prevailing Lithological Character.	Thickness.	Organic Remains.
Lower Silurian Rocks.				
4. Llandeilo formation	Llandeilo flags	Dark coloured calcareous flags	1200 feet	Mollusca, Trilobites.
3. Caradoc formation	Caradoc sandstone	Flags of shelly limestone and sandstone, thick bedded white freestone	2500 feet	Crinoidea, Corals, Mollusca, chiefly Brachiopoda. Trilobites.
Upper Silurian Rocks.				
2. Wenlock formation	Wenlock shale	Argillaceous shale	1800 feet	Marine mollusca of various orders, as before. Crustacea of the Trilobite family. No vertebrata or plants.
	Wenlock limestone	Concretionary limestone		
1. Ludlow formation	Lower Ludlow	Shale, with concretions of limestone	2000 feet	Marine mollusca of almost every order. The Brachiopoda most abundant. Serpula, Corals, Sauroid fish. Fuci.
	Amestry limestone	Argillaceous limestone		
	Upper Ludlow	Micaceous grey sandstone		

According to the more modern plan of enumerating strata on the *ascending* order, the Llandeilo, or lower formation, would be termed the *first*. It has however been thought better to retain the author's own arrangement in his Silurian System.

Here we have a series of deposits many thousand feet thick, which contain in rich abundance many distinct groupes of animal, and some vegetable remains; none of them the same with, and but few even similar to, those of our own times. To determine the order and arrangement of these was one of the most difficult works, and is among the most recent triumphs of modern geology achieved by the talents and labours of Sir R. Murchison. In the Lower Silurian system he has discovered the initial characters of the long roll of animal life, and obtained from that stony register the true geological history or sequence of the most ancient fossil races.* He considers the slates on the flanks

* The great question of 'What is the Protozoic Type? or can any peculiar and distinct series of fossils be found in rocks more ancient than the Lower Silurian? —has only very recently been fully and satisfactorily answered by Messrs. Murchison and Sedgwick. The latter, after a long and careful investigation of the slaty deposits of Cumberland and Westmoreland, has convinced himself that they contain no earlier organic remains than those found in the Caradoc sandstone, or upper part of the Lower Silurian; the great series of slate rocks lying below this being of a crystalline structure. He has also decided, on frequent and close examination of the Cambrian rocks, where the slaty series is of vast and unknown thickness, that the fossils discovered there were of the

of Snowdon as the *base line* of British fossils; and as so similar, with regard to their zoology, to the lower strata of the Silurian system, that geology must not separate them; and he believes further that in every part of the world yet observed, as well as in Britain, the Lower and Upper Silurian groups are so united by fossils common to the upper part of the one and the lower part of the other, that they form but one entire natural system. In Scandinavia and Canada, a base line of protozoic existence may be plainly traced by the gradual decrease of animal life in the descending strata, till at length all but fucoid seaweeds vanish, and the Protozoic are merged in the still older crystalline rocks.

The trap rocks and dislocations in Shropshire give proof of the alternate play and repose of volcanic action during long periods; and they show too, that the class of rocks called *Bedded Trap*, or Volcanic grit, were formed at the bottom of the sea, during the deposition of the

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same type as those of the Caradoc sandstone and Llandeilo flags. They differ, however, to a certain extent in their mineral character, which has been varied by the introduction of igneous matter more or less frequently.

Lower Silurian strata with which they are associated. " At one place they appear as currents or sheets of pure volcanic materials, at another they envelope marine remains, pebbles, sand, and fragments of rocks. Some layers consist of finely levigated volcanic scoriæ passing into sand; and all these varieties alternate so equally and repeatedly, with beds composed exclusively of shelly and marine sediments, that no doubt can be entertained that the diversified masses so arranged in parallel strata, must have been formed during the same period of igneous action. In the remote æra therefore of the Silurian system, the evidences of volcanic operations are similar to those which Lyell has noticed in the modern deposits of Sicily, where banks of existing species of marine shells, now at considerable heights above the sea, are so *interlaced* with volcanic matter, that no other deduction can be permitted than that the whole of these masses were of contemporaneous submarine formation.* But though the presence of igneous

* Murchison's Silurian System, vol. 1, p. 75. As an illustration of the mode in which ancient phænomena of the kind here insisted on were effected, Sir R. Murchison refers to Captain Fitzroy's observations on the effects

rocks in such intimate connection with the ancient Silurian strata, may fix the chronology of one class of them, it is very difficult to define the age of "intrusive trap." When basalt has broken through coal, for instance, and dislocated the strata, it must have been *since* their formation; but how long after, must remain problematical. Examples indeed are to be seen "from which it may fairly be inferred that the coal bearing strata have been forced up through the once overlying (new) red sandstone, and therefore that some of the volcanic agents which disturbed these coal fields were in action subsequently to the æra of the New Red System." *

England forms the best, as it did the first key to the classification, and arrangement in

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of the last earthquake at Concepcion; where he "has distinctly proved that the island of Santa Maria was elevated from nine to ten feet, while the rest of the coast on the mainland was only raised from two to four feet; and thus we see that not only in the same epoch, but absolutely during the same minute, recent sea shells lying in the same bed were placed at very different levels. This small measure explains the *modus operandi* as well as if the scale had been equal to that of the ancient phænomena under consideration." Sil. Sys. p. 545, *note.*

* Sil. Sys. ib.

geological order, of the Silurian strata; the fossils, however, that they contain, are everywhere so peculiar, and so nearly alike, that there is little difficulty in recognising, through them, the kindred formations in other countries: but the passage from one bed to another, on the European continent, is more gradual than in England, and the difference in the fossils less strongly marked. The oldest palæozoic rocks in France are Silurian; but no certain boundary line between the subdivisions has yet been made out, owing to the metamorphic state of the tracts in which they occur. And "in the large mountainous tracts in central Germany, no Silurian strata can be detected:* but this appears to be rather an exception to a general rule; for in almost all the countries which have been examined by the indefatigable votaries of the science, these strata with their peculiar fossils have been found; thus giving evidence of so large an extent of primæval ocean, that it is hardly possible to avoid recurring mentally to the time when the fiat of "Let the dry land appear!" had not yet gone forth.

* Murchison's Geol. of Russia, Vol. 1. p. 3.

In the small space prescribed to these little works it is impossible to say more on the copious subject of fossil remains than will amount to a very short description of the principal ones found in the several formations. The oldest monument yet discovered of animate creation is the brachiopodal shell called *obolus*, found in the lower Silurian sandstone of Russia, and its British parallel, the *Lingula attenuata*. In the oldest beds are found vast quantities of fossil zoophytes, called *Graptolites;* they resemble the "sea-pens" now found among sea-weed, and consist of a number of polypi attached to a central mass, forming a kind of compound animal. These polypi, as they are the first of known animals, so they are the least changed from the earliest up to the present time; and these little corallines differ far less from existing nature than any other of the ancient fossils. Even now they are employed in adding to the solid matter of our globe by the singular stone buildings called coral reefs; and which, like the bones of man, are formed by a peculiar process of secretion in the living animal. In their case it appears to be the carbonate of lime retained in solution in the water of the ocean, which is separated to form these extraordinary growths.

Among the Corals and Radiata, most commonly found in the Silurian rocks, are the *Cyathophyllum* and the *Catenipora escharoides* (*chain coral*) which abounds in Europe, and is not yet found in any group above the Silurian, through all parts of which it ranges. The next step is to the Encrinites or Crinoids, so called from their resemblance to a lily on its stem.*

The crustacean animals, called *Trilobites*, from the triple division of their bodies, differ much in appearance from any known form of

* These animals, as found in the Silurian strata, were "without arms, and were inclosed within stony plates:—an orifice (*a*) was left in the central part of the upper surface for the mouth; an adjacent orifice was provided, from which the undigested parts of the food could be ejected (*b*); and also a third at no great distance for the expulsion of the eggs (*c*). The mouth was provided with a proboscis, moveable, and covered with small plates; while the orifice (*c*) was covered with a little five or six sided pyramid, made up of as many little valves. The whole stony case, which in some instances resembles a little green orange, was supported on a very slender stalk, which however is seldom preserved in these elder strata. In the more advanced form, (at a later period), the mouth and proboscis are still present, but there were a number of arms projecting from the summit around the mouth; and the orifices do not exist, since the eggs were carried out at the openings for the arms."—Ansted's Ancient World, p. 34.

animal life. They have a wide range from the slaty rocks, up to the carboniferous deposits, inclusive; but their great centre is in the Silurian strata, where they are very abundant. The head is defended by a crescent shaped shield, and the body covered with moveable plates resembling those of a shrimp. They are without limbs, but had the power apparently of rolling up into a ball, like the wood louse. The most remarkable part of these animals is their large compound eyes, which are constructed on the same principle as those of the dragon fly, and arranged round two conical projections on each side of the head, so that they could see all round them without turning or moving from one spot. From this perfect and complicated organ we learn that the waters of the Silurian seas were probably very clear, and that the general laws of light were the same as in the present time.

The shells of the Molluscan animals which are the most abundantly found, and in the greatest variety of species, in the Silurian rocks, are of the order Brachiopoda; so called from having two spiral arms on each side of the mouth, which are their organs of locomotion, as well as of grasping their food. Six hundred extinct species of these have been found in the older rocks, all bivalves: which naturalists class according to the nature of the hinge attaching the valves together. The whole order is thus divided into five groups, three of which are represented in Palæozoic rocks. The genera into which these are subdivided, and which are most abundant in the older strata are the Orthis, Atrypa, Pentamerus, Spirifer, and Terebratula, species of which last are found through the whole series; and this genus is still found in existing seas. It is remarkable for the great depth of water in which it lives.*

The univalve shells of the older Palæozoic period are as remarkable, and nearly as abundant as the bivalve and crustaceous. They belong chiefly to an order but little known now, and are interesting, as they exhibit some of the most complicated forms of organization among the Invertebrata, i. e. the Cephalopoda,† which are highly characteristic of the Palæozoic period;

* It has been found at a depth of 90 fathoms.

† The genus, however, of this order, which ranks the highest in organization, i. e. the Sepia or Cuttle fish, is not found till a later period. Its representative in the fossil state is the Belemnite of the secondary strata. It is in this animal that the first rudiment of a cerebrum is discovered.

and the remains of the singular shells of many extinct species, prove the vast amount of this order in former times. They are found in abundance in every fossiliferous rock, from the older Silurian, to the chalk; and a gradual and very curious change takes place in the form of their habitations; though one genus is preserved throughout, and exists still in the Southern seas. This genus is the *Nautilus;* and it is the key by which we gain an insight into the structure of many extinct genera. The Cephalopoda, whose remains are the most frequent in the older Palæozoic rocks, had their numerous chambers placed nearly vertically, in a long strait horn, not curled as in the present Nautilus; and these are chiefly known by the generic name of *Orthoceratite.* Eighty species of these have been determined.

The earliest known remains of vertebrated animals, appear in the form of fragments of six genera of fishes, recently named and described by M. Agassiz. Four of these are new, and wholly unlike any forms in the overlying strata: they are all found in the Upper Ludlow rocks, and a few convoluted forms are found in the Cambrian rocks, which have been pronounced to belong to the class articulata, order Annelida.

No land plants have yet been found in Silurian rocks; but in North America, in both the Upper and Lower series, marine plants or fucoids, are discovered; and vestiges of such are also to be traced in the Caradoc sandstone. Throughout the whole series the grand scale on which the groups are developed, and their wide geographical range, form their most striking features: beds of the same nature, with like fossils, are found in distant continents, forming a common base, and having a unity of character which demonstrates them to have accumulated nearly at a like depth and equal temperature, for it has been sufficiently demonstrated by Prof. Forbes's dredging experiments,* that "living beings are not distributed indifferently in the bed of the sea, but certain species live in certain parts according to the depth; so that the sea bed presents a series of zones or regions, each peopled by its peculiar inhabitants." These inhabitants diminish in number as the depth increases: in the lowest region explored, only

* The very interesting paper from which this information is taken was communicated to the Royal Institution of Great Britain by Prof. Edwd. Forbes, on the 23d February, 1844. It was afterwards published in the Philosophical Journal.

eight species of Testacea were found. From one of the deepest regions massive corals were drawn up, accompanied by shell fish of the class Brachiopoda; the very same class of fossils which are to be found in the lower Silurian strata, where the decrease in the number of organized beings noticed by Prof. Forbes in deep seas, is also evident. It is therefore tolerably clear that the Lower Silurian deposits must have been those of a deep ocean, if not absolutely enveloping the earth, at least so extensive that we have not yet found any proof that it did not so envelope it, and these deposits have been found in Scandinavia, by Sir R. Murchison, identical in composition with the Gneiss on which they repose;* which, previous to their deposition, had undergone great disturbance and dislocation; so that it seems also clear that they must have been produced from the detritus of these upturned and contorted strata, which thus became exposed to the washing of the water, thrown into commotion by their elevation or subsidence.

* Murchison's Geol. of Russia, vol. i. p. 16.

§ B.

Devonian System, or Old Red Sandstone.

"The rocks known to geologists under the name of Old Red Sandstone, consist of various strata of conglomerate, sandstone, marl, limestone, and tilestone: the youngest beds of which dip conformably beneath the carboniferous deposits, whilst the oldest repose upon, and pass into certain grey coloured rocks. These grey coloured rocks form the upper part of the Silurian System,"* which latter will be found characterized in the writings of earlier geologists as *Grauwacké rocks.* These have occasionally undergone considerable upheavals and disturbances previous to the deposition of Devonian strata; at other places they are found to graduate into each other without any marked difference in the dip.

The name of *Old* Red Sandstone was given to this formation, or rather set of formations, by the elder geologists, in order to distinguish it from another bed of like appearance which lies

* Murchison's Silurian System, vol. i. p. 169.

above the Carboniferous system; but still, while mineral characters only were attended to, the two were not unfrequently mistaken for each other, even by skilful geologists: and when afterwards the embedded fossils were taken as the ground of classification, it was found that many strata not of a red colour must be reckoned to belong to the same period: it became desirable therefore to adopt some more appropriate general distinction. The author of the Silurian System had the honour here, too, of rendering another great service to science. The ancient stratified rocks of Devon and Cornwall had for a long time puzzled geologists; and, encouraged by his former success, he undertook a survey of them in company with Prof. Sedgwick, with a view to their classification. This investigation showed that fossils existed in these strata of a different type from those of the Silurian System below, or the Carboniferous above, and which from their organization appeared to occupy a middle space between the two, the lower strata exhibiting these fossils mixed with a few of the true Silurian type;—the upper, in like manner, showing them mixed with some belonging to the Carboniferous period. This seemed to justify the arranging the whole, including the Old Red

Sandstone, in a Middle Palæozoic System, which was named the Devonian.

Still some obscurity hung over the subject, for in Scotland, the Old Red Sandstone abounds in remains of fishes, while the rocks of Devonshire, to which a like age was now assigned, contain, as far as our present knowledge goes, only Mollusca and other Invertebrata. The indefatigable researches, however, of the accomplished geologist above-mentioned, have lately removed the last doubt on the subject; for, in his survey of the Russian empire, he found true Devonian strata lying over Silurian rocks, and had the satisfaction of giving the finishing stroke to his second great discovery in Geology, by demonstrating that the same beds contained the ichthyolites of Scotland,* and the Mollusca of Devonshire.

* "Prof. Agassiz acquaints us, that of the specimens which we referred to him, there are certainly eight, and probably ten species, which are common to the Old Red Sandstone of Scotland, and the Russian strata. 'So complete,' says he, 'is this identity, that the specimens of the two countries resemble each other to the extent of being confounded; often appearing to be the very casts of each other.'"—Murchison's Geol. of Russia, vol. i. p. 66.

"The calcareous flags at this spot (near Voroneje)

The fossil fish, called ichthyolites in geological phraseology, which are found so largely in the Old Red Sandstone of Scotland, differ from all existing species, and belong to an order well nigh extinct.* But the Devonian strata in the neighbourhood of Dorpat afford the most remarkable specimens of fossil fishes yet disco-

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have furnished us with a greater variety of characteristic fossils than the beds of any other locality in Russia. They not only abound in species published as Devonian types from the Boulonnois, the Eifel, and Devonshire, but also contain the remains of ichthyolites: and all this in a thickness of about seven feet!"—Ib. p. 60.

* Ganoidians, from γανος, *splendour*. The fishes of this order are covered by angular scales composed internally of bone, and coated externally with enamel. The scales are regularly arranged, and entirely cover the skin. "The *Sauroid fish*, or those which, from the structure of their teeth and other peculiarities approximate to the reptiles—the *sturgeons* and the *bony pike* (a remarkable fresh-water fish found in the North American lakes, and presenting singular analogies with extinct species) are among the most interesting fish of this order." The fish of the Palæozoic period have all a peculiarity of structure only to be found now in the shark family, the sturgeon, and the bony pike—the tail is what is called *heterocercal*, i. e. the vertebral column is prolonged into the caudal fin. In all recent species, with the above exception, the backbone terminates where the tail is first given off.—Ansted's Geol. vol. i. p. 184.

vered. These remains are so gigantic (one bone measuring two feet nine inches in length) that they were formerly supposed to belong to Saurians; but Prof. Asmus, of that University, has completely satisfied himself that they were parts of fishes,* which must have measured, according to his calculation, at least thirty-six feet in length. The species has been named from its great size, Megalichthys. Some of the fish of this period are of forms so singular that to describe them would be useless; the reader must therefore refer to works where they are figured.

The other fossils of the Devonian system are chiefly mollusca and radiata: these last seem somewhat more common in the Devonian than the Silurian strata, and many species of crinoids are found, as well as crustaceans. One of these last seems to belong to the genus Trilobites, though of very different form: it has been called *Brontes*. The remains of another crustacean, found in the Old Red Sandstone of Scotland, has been decided by M. Agassiz to have belonged to an extinct species, not unlike

* Murchison's Geol. of Russia, vol. i. p. 53. Ansted's Geol., vol. i. p. 198.

a lobster in shape, but whose length, judging from the specimens found, must have exceeded four feet.

§ C.

Carboniferous System.

IMMEDIATELY above the strata of the Devonian system are found beds of shale, limestone, and millstone grit, under and overlying in many places seams of coal, varying in thickness and in quality; but whether coal be present or not, everywhere marked by so extraordinary a cnange in the nature of the embedded fossils, that it can only be accounted for by a corresponding change in the earth's surface. Terrestrial plants and fresh water shells, which, as far as we know, are wholly wanting in the older formations here make their appearance; "and as," observes Prof. Ansted, "the carboniferous limestones, or other beds of the same age, skirt the old rocks of Cumberland, and are deposited in hollows in the Devonian rocks of Devonshire and Cornwall, it is likely that these very rocks themselves, as we know them to have been hardened and prepared for such exposure, formed the actual dry land of the period; and that upon them grew the trees and shrubs whose remains are met with in the limestones near them." *

For a time the nature of coal was a matter of some doubt, although the numerous impressions of plants found in the accompanying shales, &c. gave room to conjecture that it had a vegetable origin: but the question has of late years been set at rest by the aid of the microscope; clear traces of vegetable structure being visible in the coal itself. The plants which form it are, indeed, in so crushed and changed a state that it is hardly possible to decide on the genera, but enough of general character remains to show that they consisted for the most part of ferns of gigantic size, palms, and trees of the family of pines.

As might be expected from the nature of the deposit, the beds of coal, where they occur, vary in thickness, and occasionally *thin out*, as the miners call it; that is, diminish in thickness, till they disappear entirely: for vegetable deposits of that depth, even allowing for all the luxuriance of a tropical vegetation, could only have been formed from the accumulation of a considerable period; either in lakes, or estuaries, or

* Ansted's Ancient World, p. 76.

on the sea bottom, where great rivers carried out the trees and plants torn down by their floods, to some distance from land; and these would naturally be thinner where the shore shelved upwards. The presence of marine shells in some parts,—of fluviatile shells and fresh water limestone in others, sufficiently shows such to have been the circumstances under which it accumulated. In other places, either more distant from land, or otherwise unfavourably situated, although the strata of the carboniferous period are found almost as universally as those of the earlier systems, no coal occurs, though here and there impressions of leaves may be seen.

The quality of coal also varies very much; from the highly bituminous beds of the north of England, to the Anthracite of Wales, where the bitumen is at its minimum. The cause of this difference has been only very lately explained, for the vegetables of both being identical, there appeared no natural reason for it. The immense coal fields of North America afforded this explanation. The coal formation of this region "before its original limits were reduced by denudation, must have measured at a reasonable calculation, 900 miles in length, and in some places more than 200 miles in breadth. The strata are horizontal towards the west, and become more and more inclined and folded as we proceed eastwards. Now it is invariably found, as Prof. H. D. Rogers has shown by chemical analysis, that the coal is most bituminous towards its western limit, where it remains level and unbroken, and that it becomes progressively debituminized as we travel south-eastward towards the more bent and distorted rocks. Thus, on the Ohio, the proportion of hydrogen, oxygen, and other volatile matters, ranges from forty to fifty per cent. Eastward of this line, on the Monongahela, it still approaches forty per cent., where the strata begin to experience some gentle flexures. On entering the Alleghany mountains, where the distinct anticlinal axes begin to show themselves, but before the dislocations are considerable, the volatile matter is generally in the proportion of eighteen or twenty per cent. At length, when we arrive at some isolated coal fields associated with the boldest flexures of the Appalachian chain, where the strata have been actually turned over, as near Pottsville, we find the coal to contain only from six to twelve per cent. of bitumen; thus becoming a genuine anthracite."* It appears from the researches of modern chemists, that when vegetable matter is buried in the earth, it decomposes slowly, and evolves carbonic acid gas; parting in this manner with a portion of its original oxygen. Then it becomes altered in its composition, and is gradually converted into lignite, which contains a larger proportion of hydrogen than is found in wood. A continuance of decomposition changes the lignite into common or bituminous coal, chiefly by the discharge of carburetted hydrogen (coal gas). The inflammable gases which are always escaping from mineral coal, contain carbonic acid, carburetted hydrogen, nitrogen, and olefiant gas: the disengagement of all these gradually transforms ordinary, or bituminous coal into anthracite. The disturbances, therefore, produced by volcanic action would promote the escape of volatile matter, both by causing fissures in the earth, and by subjecting it to a greater degree of heat. This view of the matter is further confirmed by the transformation into anthracite, which bituminous

* Trans. of Ass. of Amer. Geol., p. 470, cited in Lyell's Travels in North America, which see for further details on this subject.

coal is often found to have undergone in the neighbourhood of trap dykes.*

Of course the regular superposition of beds will be somewhat affected by the locality;—that is, strata which are found in some places will be wanting in others, as are the Silurian strata in some parts of Scotland;—or they will be represented by some other mineral substance containing the like fossils, and these are called equivalents;—or they will be altogether broken up and displaced by subterranean forces, or washed away by water. Still a certain order may be expected; and it will most generally be found that the quartzose conglomerate, and sandstone of the upper part of the Devonian system are followed in an ascending series by the following strata:

7. Lowest New Red Sandstone with calcareous concretions.
8. Upper coal measures with fresh water limestone.
5. Main coal.
4. Lower coal and ironstone.

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* See Turner's Elements of Chemistry, Part ii. (organic), p. 1240, 8th edit., edited by Baron Liebig and Dr. Gregory, 1847.

3. Millstone grit.

2 and 1. Carboniferous or mountain limestone, and Shale, lying frequently as it were in the trough created by the upheaval of parts of the Devonian strata below.

The carboniferous, or mountain limestone, owes its calcareous matter chiefly to the works of the coral polypi: it seems, therefore, probable that the force by which the Devonian strata were upheaved from beneath the primæval ocean, had broken up so much of the surface as to occasion a considerable deposit of muddy and stony matter when the troubled waters had time to subside, and hence the shales which lie at the base of the carboniferous strata. Upon this formation where the sea bottom was sufficiently elevated, the coral animal which usually works in shallow waters, built up its reefs, which we know from actual experience can be done very rapidly; and if a gradual subsidence followed the violent upheaval, the little creatures would continue their works so as to keep pace with it, which may account for the great depth which this formation sometimes exhibits. After the last subsidence beds of vegetable remains accumulated, and these again were followed by fresh depositions of mud and sand, and fresh beds of vegetable matter. This must have been effected during a comparatively tranquil period: but it was succeeded, apparently, by a season of new and yet more violent convulsions than had before occurred. It is hardly possible to describe the extent of disturbance and dislocation of strata which the coal mines disclose. In some places volcanoes appear to have poured forth torrents of lava, which forced their way through the coal beds; arresting the progress of the miner by a wall of igneous rock, which has left the rocks through which it passed altered both in appearance and composition, in consequence of the heat to which they have been subjected. In others, enormous cracks, extending for many hundred yards, or even for miles together, may be traced in the more brittle rocks: frequently the irresistible subterranean force has snapped asunder the strata, and one side of the broken bed has been lifted high in the air, or has sunk into a deep hollow beneath, and if the force was not sufficiently energetic to break up in this way the whole group of overlying matter, it raised up the strata upon a line or point; thus producing a saddle shaped, or dome-like elevation, according to the circumstances of the case.* Every coal field is so split asunder and broken into small fragments by what are called "faults," that it is impossible to doubt of the enormous internal force which must have been in action at the latter part of the Palæozoic period.

As far as the world has yet been examined by geologists, no country has been found exempted from these convulsive upheavals, excepting a large tract in European Russia, where the strata have remained so undisturbed, save by a very gradual process of elevation, that Sir R. Murchison and his companions found it difficult in many places to discover what were the underlying beds; and it was not till the travellers approached the Ural mountains that igneous rocks, and upheaved and dislocated strata, were again discoverable.

Before entering on the consideration of the fossils of this period, it may be well to remark that the non-occurrence of remains in certain strata, is not a complete proof that, at the time those strata were accumulating, the animals found in the beds next above them, had not yet come into existence. The Devonian system

* See Ansted's Ancient World, p. 106, et seq.

shows no trace amid its strata of the plants which grew on their upheaved surface, which are only to be found in the system which succeeds it in order of time. Thus also, the bones or shells of animals coæval with one set of strata will be found embedded in the next: for it is rare to find more than disjointed skeletons, which must have been wave-tossed for many a year before they were finally entombed. This will account for the absence of bones of reptiles or birds in the strata of the Carboniferous System, although we have undeniable proof that such did exist at that time. This proof is gained from a deposit of New Red Sandstone, in such close connection with the coal measures, and exhibiting so many of the plants and shells belonging to the carboniferous period, that it may be assumed to be the upper stratum of that series.*

When sand is wet it receives impressions very distinctly, and, unless disturbed, retains them: thus these sand rocks, which are nothing more than the sediment of the detritus formed by the

* Murchison's Geol. of Russia, vol. i. p. 140. That geologist conceives the stratum called by German miners *Rothe-todte-liegende*, to be the equivalent of this Lower New Red Sandstone.

wash of the sea, subsequently consolidated, were once capable of receiving and retaining foot marks or other traces of birds or animals which might traverse them, whilst forming a shore washed by the sea. If after the impressions were made, a thin coating of some other substance were deposited, the consolidated stone would be liable to crack in this place, and thus the foot-prints of animals which roamed over that primæval world have been preserved and offered to our observation. In the sandstone formation accompanying the coal measures of North America, such foot prints have been discovered, though it has not yet been decided whether they belonged to reptiles or birds; but at any rate they afford a decided proof that terrestrial animals were not long in making their appearance after terrestrial plants had prepared the way for them. Some remains of insects have also been found in the fresh water limestone of that period.*

The vegetable remains which so abound in the strata of the Carboniferous System show an immense proportion of fern-like plants, though of so large a size that no European plant can at

* See Ansted's Ancient World, p. 91.

all be compared with them, and the nearest resemblance is found in the tree ferns of Australia and the South Sea Islands. This is remarkable; for the southern part of Australia differs not far from the latitude of England on the other hemisphere, and thus we see that these apparently tropical plants *might* exist in a climate exposed to considerable variations of temperature. Another genus of plants is also found in abundance, though not in so large a quantity as the ferns: this has been termed by geologists *Calamites*, and appears from the fragments remaining to have belonged to the family of Equisetum, the common mare's tail of our marshes; but its size was enormous, having a stem, as has sometimes been found, of more than a foot in diameter. Besides these, two sorts of forest trees have been observed: the one, called *Lepidodendron*, is thought, from some peculiarities in its structure, to have formed a kind of connecting link between the family of pines, and that of the Lycopodiaceæ (club mosses):—the other, termed Sigillaria, is supposed to have resembled in some respects the Zamia of New Zealand.

The marine animals of these strata differ considerably from those of the older beds. Some

Trilobites still remain, and Brachiopoda are numerous; but excepting the Terebratula,—some species of which have survived even to the present day, and which therefore evidently has the power of accommodating itself to great changes,—the species, and frequently the genera, differ widely from those of the older formations. The Productus, of which M. de Verneuil enumerates twenty-six different species in the carboniferous strata of Russia,* seems to be among the shells most characteristic of this period: Cephalopoda also abound, but they have changed their type, and instead of the orthoceratite, with its long strait shell, which had been so characteristic of the older rocks, and which nearly disappears from those of the Newer Palæozoic, we find the twisted shells of Goniatites and Nautilus. But there would not be space here to enumerate the characteristic shells of this period, which must be learned from larger works. The above will suffice to show in some measure the degree of change which had taken place.

"The reader who has followed us in our enumeration of the carboniferous fossils in the different parts of the empire of Russia," observes

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* Geol. of Russia, vol. ii. p. 255.

Sir R. Murchison in concluding his notice of this period, "will not be less struck with their general resemblance to those of the same age in Western Europe, than with the marked differences between them and the forms in the older Palæozoic rocks of this region. One or two species only of the Devonian fauna have been detected. We invite attention," he continues, "to the remarkable proofs which Russia affords, of an almost completely new creation of species in the carboniferous epoch. . . . Of ichthyolites, so remarkably abundant in the Devonian epoch, there are very few traces in the carboniferous limestone. The few which have been discovered are, however, quite distinct from the remains of fishes of the preceding period.—On the whole, the review of the carboniferous fauna of Russia indicates numerous forms which are identical in deposits of the same age in the British Isles, North America, and Russia; thus affording the strongest proofs that the conditions of equable climate which prevailed over enormous areas during the Silurian and Devonian epochs, were continued in quite as great intensity during the succeeding age." *

* Geol. of Russia, vol. i. p. 135, et seq.

§ D.

Permian System.

When Sir R. Murchison was engaged in his survey of Russia, he observed a group of strata whose mineral character was very various, but which appeared to him and his fellow geologists to be "characterized by one type only of animal and vegetable life. Convincing ourselves in the field," says he, "that these strata were so distinguished as to constitute a system, connected with the carboniferous rocks on the one hand, and independent of the Trias (the three lower beds of the Secondary formation) on the other, we ventured to designate them by a geographical term derived from the ancient kingdom of Permia, within and around whose precincts the necessary evidences had been obtained."* This distinction so recently made has hardly yet been generally acknowledged, but as it affords a convenient mode of classification it is here adopted.

The equivalents of these Russian strata appear to be in England:

1. Certain schistose beds lying next above

* Geol. of Russia, vol. i. p. 138.

the Lower New Red Sandstone (the Rothe-todte-liegende of Germany).

2. Magnesian limestone.

In Germany these are represented by

1. Kupfer Schiefer, or copper slate, which lies above the rothe todte liegende (or *red coloured dead strata*, so called from being devoid of metal).
2. Zechstein ; and perhaps,
3. The lower part of the Bunter Sandstein or Gres Vosgien of France.

These formations, however named, and where-ever found, have one character in common, i. e. a paucity of organic remains; whence it would appear that the waters of this period must have been charged with some ingredient unfavourable to animal life. The cephalopoda, so numerous during the carboniferous period, disappear almost entirely, while 200 species of Brachiopoda to be found in the carboniferous strata, dwindle away to ten; about twenty new species being introduced. Other species suffer a like diminution, with the introduction of but few new species. Fishes are the most abundant; of these 43 species are found, 42 of which are peculiar to this formation. But the most remarkable of the fossils found in these strata are five species of Saurians, of which one was found in Germany in the copper slate at Mansfeld, three were found in England, near Bristol, and two in Russia.*

The strata of this system are rich in copper,† not however in the form of veins or ores, but merely as a general impregnation from the soluble salts of that metal, and in this cupriferous alluvium lumps of magnetic iron ore are found which will be farther considered in Chap. V. Probably the abundance of copper held in solution in the waters of this period may account for the decrease of animal life.

* Geol. of Russia, vol. i. p. 226.
† See note to chap. v.

CHAPTER IV.

The Secondary Period.

§ A.

Upper New Red Sandstone, or Triassic System.

THE Lower New Red Sandstone having been separated from this group, there remain in England but two formations, belonging to this system, and these not always very well defined. These are the Upper New Red Sandstone and certain red marls abounding in salt. In Germany that part of the Bunter (coloured) Sandstone, which lies most above the Zechstein, is succeeded by a stratum of *Muschelkalk*, or shell limestone, which is wanting in England: * this is followed by the Keuper, which answers to

* There is perhaps one exception to this. "In the neighbourhood of Axmouth, in Devonshire, and in the cliffs of Westbury and Aust, in Gloucestershire, on the banks of the Severn, a dark coloured stratum is seen, well known by the name of the "bone bed." It abounds

our saliferous marls, and these three beds have been grouped by continental geologists under the common name of Trias.

The Upper New Red Sandstone, wherever found, is remarkable for the almost total want of organic remains, the convulsions of the period following the deposition of the coal, having probably destroyed a large portion of the then inhabitants of the land and sea; and the trituration which must have taken place during a period of such disturbance, and of which we see the results in these coarse sandy beds, probably reduced their remains to a like state of comminution. In the Muschelkalk fossils re-appear in abundance, but they are either entirely new genera, or of species which differ considerably from those of the Palæozoic Period.

But though the Upper New Red Sandstone affords few organic remains; yet, like the Lower formation of the same kind, already described, it affords irresistible evidence of the existence of animals, by the preservation of their footsteps; a portion of these have been supposed to be those of birds, some of them common waders,

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in the remains of Saurians and fish, and contains species well known in the continental Muschelkalk. See Lyell's Elem. of Geol. vol. ii. p. 82.

others of a gigantic size, the length between one impression and the other being not less than from four to six feet, and the footmark itself fifteen inches in length. The other footprints have been referred to tortoises and turtles, with the exception of one, which bears a great resemblance to an ill formed human hand, but of very various size, implying a great difference in the dimensions of the extremities; the hinder foot measuring eight inches by five, while the fore foot is not more than four inches by three. A few years since some fragments of bone were found in the very quarries where these marks occurred, and they have been referred by Prof. Owen to a batrachian reptile: it appears therefore probable that this creature was a gigantic animal of the frog kind, or perhaps forming the link between frog and crocodile, as some of the peculiarities of the skeleton indicate. Worm tracks, and the scratching of a small crab on the sand, as well as the marks of drops of rain are also visible in slabs of this formation. The remains of two other animals, which appear to belong to the lizard tribe, have also been found in the New Red Sandstone beds near Shrewsbury. These, too, exhibit very extraordinary modifications of form.

It is, however, chiefly in the Muschelkalk that the bones of reptiles are found: they belong to the marine saurians, as might be expected from the evidently marine origin of this stratum; but these will be spoken of in the next section. The fishes of this period no longer exhibit the peculiarity in the tail fin which is seen in all those of the Palæozoic age.

The fossil plants are found chiefly in the marly beds of the Keuper; the trees of the carboniferous system have entirely disappeared, and though there are still ferns and equisetaceæ, they are apparently of different species. Those of the Zamia tribe are the most abundant.

The red saliferous marls of Gloucestershire and Worcestershire are the sources of the medicinal mineral springs in that part of England. These waters in rising through the superincumbent beds—of Lias chiefly—may dissolve and carry off some of the substances there found, but probably most of their medicinal virtue depends on the Bromine and Iodine which have been detected in them, and which, being among the products of sea water, would be found in these deposits of a former ocean.

§ B.

Liassic Group.

"Lias" is a provincial word, supposed to be a corruption of *layers*—this rock having a rib-band-like appearance when cut through, consequent upon the alternation of argellaceous limestone, clay, marl, and sand. This formation extends in England in a diagonal line from Lyme-regis, on the coast of Dorsetshire, to the coast of Yorkshire, near Whitby; but it is found largely in most parts of Europe,* excepting Russia. The peculiar aspect which is most characteristic of the Lias in England, France, and Germany, is an alternation of thin beds of limestone with a light brown weathered surface, separated by dark coloured narrow argillaceous partings; so that the quarries of this rock at a distance appear striped. Lias is found on the Alps, where it contains several metallic ores, and exists also in Northern India. In England it mostly forms level plains below the Oolitic

* Its thickness varies from 500 to 1000 feet. Lyell's Elements of Geol., vol. ii. p. 50.

hills, excepting in Leicestershire, where it forms the range called the Wold hills: it occurs also on some of the Mendip hills.

This formation abounds with fossils, most of them of new species: the plants resemble those of the Triassic system, but fragments of true coniferous wood have been found. Marine shells are abundant, which makes it probable that these strata also were deposited beneath the ocean, and raised by a very gradual process of elevation. The shell which most abounds is that of a species of cephalopod, named *Ammonite*, and another belonging to a species of cuttle fish, which has been termed *Belemnite*. Corals are not found, but there are abundance of Crinoidal remains, those of the Pentacrinites are in such quantity that there exist beds of some inches thick entirely composed of them. But the most interesting of all the fossils of the Lias are those of the enormous reptiles which form the main characteristic of this period, though not exclusively so, since some of the most remarkable genera are found also in the Muschelkalk. These singular creatures have been named respectively *Ichthyosaurus* and *Plesiosaurus:* and many species of them appear to have existed,* both at this period and later, during the secondary epoch. Both attained to a length of nearly 30 feet,† both inhabited the ocean, and both were carnivorous, as might indeed have been inferred from their structure, but which is proved beyond a doubt by the actual presence of the remains of fish, and other marine animals, in the abdominal cavity of some specimens. The head of the Ichthyosaurus was large, and resembled that of a crocodile in many respects; it had four paddles, which took the place of the short legs and feet of the land reptiles, and the vertebræ of the tail are numerous enough to have been very long: it has been suggested, however, by Prof. Owen, that a powerful fin was attached to this part. The body is deep, and has a fishlike shape, though the structure of the bones is truly reptilian. The Plesiosaurus was yet more

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* Ten species of the Ichthyosaurus have been distinguished, and eighteen of the Plesiosaurus; but six of these latter occur in strata of later formation than the Lias.

† "The largest *complete* skeleton of a Plesiosaurus yet found measures 18 feet in length, but there are fragments of individuals which appear to have been nearly twice as long." Ansted's Ancient World, p. 161.

extraordinary in its formation; for, with a body somewhat resembling that of the Ichthyosaurus, save that it was less massive, it had a neck exceeding that of the swan in proportionate length, for the neck of this bird has only twenty-three vertebræ, while that of the Plesiosaurus had upwards of thirty. The paddles were long, the body slender, so that it must have had wonderful power of darting on its prey, although it was no match for its more powerful congener, in whose stomach fragments of its bones have been found. Two more genera of Saurians are found in the Lias, one belonging to the order of Pterosaurians, or flying lizards—the other of the crocodilian family, but they are more abundant in the next formation.

§ C.

Oolitic System.

THIS name is derived from the appearance of many of the limestones of this series, which seem to be made up of small egg-shaped particles, but as this is a character found also in many other formations, this is often distinguished as *Jura limestone*, from its large developement in that mountain-chain. A reference to the table will show the various members of this system. In some places the lias passes gradually into the Oolite, but in others they are sufficiently unconformable to show that some time must have elapsed between the last of the one series and the first of the other: hence the distinction into different systems; which, indeed, is justified by a considerable variation in the fossil remains.

Throughout the secondary formations no true coal is formed, but occasionally in the Oolitic series, lignite more or less bituminised, occurs, though it is never enough so to be really valuable; and remains of vegetables are found in several of the strata. But wherever found they differ from those of the carboniferous period, though they still belong apparently to genera which may be ranged in the great families of palm and fern.* The stems of some of these

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* "In New Zealand, whose latitude is the same as that of a great part of Europe, the ferns and fern-like plants are by far the most numerous, covering immense districts, replacing the grasses of other countries, and giving a character to all the open land, whether hill or plain. Some of these ferns grow to thirty or forty feet in height. The most valuable timber belongs to the

are called petrified birds' nests by the Portland quarrymen; they have become silicified, and sometimes approach to chalcedony in their mineral character.

The coral rag at Steeple Ashton, in Wiltshire, is so abundant in the fossils from which it is named, that it has been conjectured to be the remains of a coral reef, and the Caryophyllia which are so abundant there, are still "among the most remarkable for their activity in building coral islands and reefs in the existing tropical and southern seas."* The Bradford clay affords a remarkable species of the crinoid type, called *apiocrinite*, or *pear encrinite*, which is also a marine production, and indeed generally the fossils are of a sufficiently marine character to show plainly that these beds were formed beneath the ocean, though not very far from land, as the remains of vegetables, and of an insect resembling a dragon-fly, testify. The Ammonite and Belemnite characterize the Oolite

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Coniferæ, which, with the palms and tree-ferns form the prominent objects in the forest scenery. The resemblance of this vegetation to that of the Carboniferous and Oolitic periods as exhibited by their fossil remains is too remarkable to be past over in silence."—Ansted's Geol. vol. i. p. 338, *note*.

* Ansted's Geol. vol. i. p. 390.

no less than the Lias, and in the lithographic limestone of Solnhofen, fish, crustaceans, insects, mixed with the cephalopods are frequent. Most of the fish are referred by M. Agassiz to the Ganoids, but the tail has not the peculiarity of the ancient fish of that order.

The remains of marine Saurians are abundant in the Oolitic beds, but the Ichthyosaurus and Plesiosaurus are less frequent and not so well preserved as in the Lias. A new genus, allied to the Plesiosaurus, larger, but without its long neck, has been named by Professor Owen *Pliosaurus.* A tooth of this animal has been found seven inches in length, of which four inches were implanted in the jaw, and that part of the jaw in which the teeth were inserted measures three feet in length. The size of this creature must have exceeded that of any other known genus, for one femur, or thigh bone, measures twenty-six inches in length, and thirteen inches across at the broad part. "The remains of this genus have been chiefly met with in the Kimmeridge and Oxford clay, and two species have been determined from these localities."* Five genera of Crocodilian rep-

* Ansted's Geology, vol. i. p. 406.

tiles have been found in various parts of the Oolitic series: one of these, the *Teleosaurus* also occurs in the Lias. The *Cetiosaurus* appears to have been a marine animal, but so far resembles the crocodile that the extremities are armed with strong claws. The bones, too, resemble those of the crocodile in their arrangement. Of this genus four species have been found, and the vertebræ are of so enormous a size as to justify the conclusion that the animal must have attained a length of nearly sixty feet. No teeth or jaws have yet been foun

Three genera of these extinct reptiles have been formed into a distinct order* by Professor Owen: these appear to have been gigantic crocodile-lizards of the land, and have the bones of the extremities of so large a proportionate size that they more resemble those of the pachydermal quadrupeds, than those of any known reptile. One of these, the *Megalosaurus* occurs in the Stonesfield slate: the remaining two are confined to the Wealden deposits, which will presently be noticed. The thigh-bone and the tibia of the Megalosaurus each measure three

* Dinosaurians. They are termed Megalosaurus Hylæosaurus, and Ignanodon.

feet, the bones of the foot measure thirteen inches, the whole length of the animal is undecided, but from the size and form of the ribs, the trunk must have been deeper in proportion than is the case in most Saurians.

In the lithographic limestone occur the bones of another class of Saurians, yet more anomalous: the Pterodactyl. This creature in some parts of its form must have borne some resemblance to the Bat; but its long snout appears almost like the beak of a bird, though in fact it is the true jaw of a reptile, and is armed with a long row of teeth.

It is in the Stonesfield slate that some fragments of a lower jaw have been found which were referred by Cuvier to the class *Mammalia*. They are the only ones yet found in the secondary formations, and appear to have belonged to the Marsupial family, of which so many genera are found in Australia. They have been named by Professor Owen *Amphitherium* and *Phascolotherium*.

§ D.

Wealden Formation.

This formation, which extends along a part of the southern coast of England, (from Portland to Hastings) and of which traces are found on the opposite coast of France, is chiefly remarkable as being evidently a fresh-water deposit, containing plants, fresh-water shells, and bones of terrestrial animals in abundance. It is further remarkable from affording a proof of the great change which has taken place in the relative position of sea and land; since it is hardly to be doubted that at some period what is now a part of the English Channel must have been partly lake and partly forest. The depression of the present sea bottom too must have been fluctuating, for in the western part of Sussex the upper beds of the Wealden alternate so far with the lower of the marine strata which overlie them, as to show that probably this part was an estuary into which the sea occasionally made its way; near Weymouth and the Isle of Wight too, oysters and cockles are seen, which testify to at least a brackish state of the water at the time they existed.* In some other parts of Europe there are deposits resembling the Wealden: in all, the presence of iron ore seems to be a distinguishing characteristic.

In the Isle of Portland, above the Oolite, there is a stratum of about a foot thick of black loam, where the remains of stems and roots of trees are found silicified, and, from their position, evidently in the very spot where they grew; the loam itself having probably accumulated round them from the decay of their leaves and branches: it is therefore evident that the sinking of the surface must have been very gradual. The structure of these trees is coniferous, and similar wood is found in a like situation with respect to the Portland formation, on the coast of France in the Bas Boulonnois, at the junction of the Oolites and the Weald in Buckinghamshire, and in the vale of Wardour.† It is above this submerged forest that the Wealden beds of sand and clay have been deposited, and it seems only partially raised again, since ac-

* Murchison. Geol. Trans. 2nd series, vol. ii. Martin, Geol. Mem. on Western Sussex. See also a Memoir on the Weymouth district by Dr. Buckland and Sir H. De la Beche. Geol. Trans. 2nd series, vol. iv.

† Ansted's Geol. vol. i. p. 368.

cording to all appearance this dense forest must have extended all across that part of the present ocean which now separates England from France.

In the sands, which formed in the waters which gently rose above the sinking forest, immense numbers of sea and land Tortoises, Crocodiles, Plesiosauri, Megalosauri, &c. as well as enormous terrestrial reptiles lie buried, along with some bones of birds of the order Grallæ or waders,* and over the whole a clay bed has accumulated, apparently of fresh water origin. The other beds of a like nature which occur elsewhere probably owe their existence also to more or less extensive estuaries. The Wealden group in some places shows an aggregate depth of not less than 800 feet.

§ E.

Cretaceous System.

The cretaceous rocks may be divided into two groups, the lower one, which rests on the

* These are the first *bones* of birds which have yet been found, although there is evidence of their existence much earlier.

Wealden strata, or, in their absence, on the Oolite, may be termed the Green-sand; the upper, the chalk formation; very different in appearance and mineral composition, but united by their fossils. The Green-sand is so named from the numerous particles of Silicate of iron contained in it, whose green colour gives a tinge to the whole: between the upper and lower is interposed a parting of clay of a blue colour, and very fossiliferous, called *Gault.* This is best seen about the cliffs of Folkstone in Kent. The chalk is too well known to need description: its composition was for a long time a puzzle to Geologists and Naturalists; but from the researches into its texture which have lately been made with powerful microscopes, it appears probable that it is nearly, if not entirely composed of calcareous matter elaborated by animals. Mr. Lonsdale, on examining portions of white chalk from different parts of England carefully rubbed down in water, found that what appeared to be white grains were in fact fragments of minute corallines, or entire Foraminifera and Cytherinæ; and Ehrenberg has furthermore discovered that the chambers into which these Foraminifera are divided are actually often filled with thousands of well preserved Infusoria, and other microscopic bodies, which abound in every minute grain of chalk. These bodies are calcareous; but others have been detected in the flints of the chalk, which, like the Infusoria in tripoli, are siliceous. These forms are especially apparent in the white coating of flints, often accompanied by innumerable needle-shaped spiculæ of sponges, and the same are occasionally visible in the central parts of chalk flints, where they are of a lighter colour. But even where no trace of organization is perceivable, it seems probable that chalk has an animal origin, for it has been observed that at the bottom of the lagoons formed by coral reefs, a soft white calcareous sand is formed from the decomposition of the coral, which when dried is not to be distinguished from common white chalk.* Although the flints which so generally accompany the chalk cannot be thus examined in the course of formation, yet it is so often found that some marine production, such as corals, sponges, &c. form the nucleus of the nodules, that perhaps it may be assumed with some degree of certainty that these too are organic in their origin.

The fossils of the cretaceous system are

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* Lyell's El. of Geol. vol. i. pp. 56, 392.

strictly marine; several of them, such as the Terebratulæ, are known to live at the bottom of the sea, where the water is tranquil, and of some depth. One of these shell-fish, the Catillus, became extinct, apparently, at the end of this period, as it has never been found in any later formation.

Fish, sea-weeds, and even pieces of wood, are found in the Cretaceous strata; but these latter have the appearance of having drifted from a distance; being always pierced by boring shells, such as the Teredo, &c. and the bones of large marine reptiles have been found, both in the Green-sand, and the English chalk. The same fossils are found in the Maestricht limestone beds.

In many parts of the world, in North America especially, no white chalk occurs; but strata whose fossils show them to have belonged to the Cretaceous period, are found very generally; which countenances yet further the above opinion as to the origin of the chalk formation; since, if that be correct, it could only accumulate under circumstances favourable to the increase of that class of animal. How great that increase must have been, may be judged by the circumstance that the chalk, where found, in

England and the north of France, generally has a depth of from 1000 to 1500 feet.

The cretaceous system, through a large part of Europe, is represented by beds which differ considerably in their mineral character; but in Russia the true white chalk again appears in the country about the Don, in great thickness,* towards the north however it dwindles to a thin bed, and finally thins out altogether. It is remarkable that here the chalk actually rests, though not conformably, on the Carboniferous strata; all the intermediate systems being wholly wanting: a proof, perhaps, that the convulsions following on the Carboniferous period, placed this part of Russia above the sea level for a considerable time.

The close of the Secondary Period appears to have been marked by an unusual activity of subterranean forces; for most of the mountain chains, of which we have any geological knowledge, appear to have emerged from the ocean about this time; as is proved by the nature of the strata which form some of their highest

* An artesian well had been carried to a depth of 630 feet at Lugan without any indication of a change of rock. Murchison's Geol. of Russia, vol. i. p. 266.

peaks, and which generally belong to the later Secondary systems. The Alps, the Pyrennees, the Caucasus, all appear to have risen from the ocean after the formation of the cretaceous deposits; and the shells brought home from the Himalaya belong to the Oxford clay, which is a part of the Oolitic system; thus linking this great chain with the Alps as to the period of its first upheaval. I say *first*, because there is every reason to suppose that these great mountain chains gained their present altitude by successive movements; which, after the first breaking up of the strata by volcanic fires, gradually raised the whole surrounding country also from a sea bottom,—where these peaks protruded, and appeared above the waters as islands,*—to high table land. Every one who has travelled in a mountainous country is aware that the highest mountains scarcely strike the eye as such, from the great elevation of the table land out of which they rise.

It is evident, nevertheless, that the intense

* It is observable that at the foot of these raised and contorted secondary strata, Tertiary beds are found, lying *horizontally*; showing that they must have been deposited *after* the elevation of the mountain ranges which they thus skirt.

heat attending these first upheavals (for igneous rocks are everywhere found protruding in and near mountain chains,) must render the examination of strata much more difficult; since in the metamorphic state assumed by rocks in contact with lava torrents, all traces of organized life are, for the most part, obliterated. It was a rare good fortune, therefore, which enabled the enterprising explorers of the geology of Russia to discover *encrinites* "encased between two great parallels of eruption in pure white saccharoid limestone."* Sir R. Murchison observes farther that the limestone in which the encrinite was found, "being precisely on the strike of the masses on the mountain of Sugomac, and at Soimanofsk, left no option but that of admitting that the associated stratified masses, however crystalline they may now appear, were once quartzose sandstones and grauwacké, formed under the sea, at a period when palæozoic life prevailed."†

It has already been noticed that a part of

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* If we may depend on the account given by ancient writers of the finding of *apuæ*, a kind of fish—in the marble quarries of Paros, it is a farther proof of the metamorphic character of this rock wherever it occurs.

† Geol. of Russia, vol. i. p. 426.

Russia appears to have been above the level of the waters at a very early period, since the deposits which elsewhere follow the Permian, or Magnesian limestone, are here wholly wanting, up to the Jura limestone: in conformity with this, the Ural chain, which separates Russia in Europe from the Asiatic steppes of Siberia,* and which everywhere bears marks of intense

* Sir R. Murchison conjectures that a large part of these steppes must have been dry land at the time the Permian deposits were in a course of formation: for these last are impregnated with copper, apparently the result of volcanic action, by which soluble salts of that metal were first formed, and then dissolved in the surrounding ocean; while the plains to the east of the Ural afford no cupriferous alluvia. From this he infers that these plains were dry land at the time when the Permian sedimentary strata, which offer no real metallic veins,—were undergoing an impregnation with salts of copper from the waters which covered them. He gives a curious account of something of a like impregnation in modern times, which, as this expensive work is in few hands, I copy.

" Some years ago a peat bog, near Dolgelle, in N. Wales, was found to contain so much copper that certain speculators dug out the peat, and burning it, extracted a small quantity of ore. Mr. A. Aikin has furnished an account of the phenomena, ' The peat was black, compact, and differed from the ordinary appearance of that substance, in containing a few small bits of bluish-green, compact carbonate of copper. The section of some igneous action, appears to have been one of the earliest upheavals; for, according to the geologists already so often referred to, the widespread Permian deposits which "repose upon carboniferous strata throughout more than two-thirds of a basin which has a circumference of not less than 4000 English miles;"* are derived from the materials of the older strata of the Ural;† which must, therefore, have been in a state of disturbance previous to that deposition; but a disturbance evidently beneath the waters; and this

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pieces of wood found there, showed bluish or greenish stains, indicative of the presence of some salts of copper, and also grains of irregular form, of copper in the metallic state. The copper contained in the bog probably originated from copper pyrites (a mixture of the sulphurets of iron and copper) forming a vein, or dispersed in some rock so situated that rain water falling on its surface, and there dissolving them, the mixed sulphurets of iron and copper derived from the decomposition of the above-mentioned sulphurets might flow down into the bog. Bog water contains vegetable acid and extractive matter proceeding from the conversion of recent vegetables into peat, which substances, together with the carburetted hydrogen gas, evolved during such conversion, would be quite adequate to the production of metallic copper and its carbonate, especially when assisted by the action of the oxide of iron contained in vegetables." Geol. of Russia, vol. i. p. 169.

* Geol. of Russ. vol. i. p. 220. † Ib. p. 168.

probably took place about the period that produced the rents and faults so universally found in the Carboniferous system.

The immense changes in the relative position of land and sea which have evidently taken place, as well as the large eruptions of heated matter so apparent in many parts, may well account for the disappearance of many genera of organized beings, if their position exposed them to the effects of these convulsions, without requiring any such general destruction at particular epochs as some have supposed. The genus *Terebratula*, whose proper dwelling is in the deep sea, and was therefore likely still to find a place notwithstanding some changes, is still existing;—so also is the *Nautilus*. The distinction into Periods, therefore, though a convenient, is also in great measure an arbitrary one. Reptiles which have been considered so peculiarly characteristic of the Secondary Period, we have seen, did actually exist when the Lower New Red Sandstone was in the course of formation, and their bones even, have been found towards the close of the Palæozoic æra. In like manner, mammalian quadrupeds have been considered characteristic of the Tertiary formations, yet they already begin to appear in the Secondary; though, as far as we yet know, they belonged to the family of Marsupialia only, which may be considered as forming the link between the oviparous reptile and the viviparous quadruped: the young of the Marsupialia being sheltered in a pouch, after their exclusion from the matrix in a very imperfect state,—until they have attained the requisite powers of locomotion.

It is remarkable that the forms of the organized beings belonging to the Cretaceous system are, for the most part, such as belong to a very deep sea: so that it would appear that a gradual sinking of the surface must have taken place during the greater part of the Secondary Period: the effects of its fresh upheaval will be considered next, in what is called the Tertiary Period; to which I now proceed.

CHAPTER V.

Tertiary Period.

ABOVE the chalk formation, and in the hollows or basins which were once the bottom of gulfs or estuaries, lie the strata termed the Tertiary. During the two former periods, so large a portion of the globe appears to have been submerged, that the deposits of the great ocean could be ranged in systems which were almost universal: but gradually larger and larger portions of dry land seem to have been exposed, and after the Cretaceous system, we no longer find much continuity of strata. Deposits appear to have been formed in large lakes, or inland seas, at intervals invaded by the ocean: these have again been drained or raised, and laid bare. Portions of land have been submerged while others have risen; but each spot henceforward seems to have its own peculiar history, and no longer affords a clue to the general history of the whole globe. This may be exemplified in the Paris basin, which is supposed to belong to the oldest of the Tertiary formations. Here there is, first, a fresh water stratum of clay and limestone; then, a stratum of marine limestone; a second fresh water formation succeeds, which contains gypsum (plaster of Paris); a second marine stratum of sand and lime follows this, and lastly a third series of fresh water strata.

In proportion as these peculiar histories are numerous, the science of Geology becomes complicated; and one of the most accomplished of the writers on the subject has attempted to classify this period in the manner shown in the table given at the beginning of this work.* It

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* Let him speak for himself. "In addition to the difficulty presented by the want of continuity, when we endeavour to settle the chronological relations of these deposits, another arises from the frequent dissimilarity in mineral character of strata of contemporaneous date. The identity or non-identity of species is also a criterion which often fails us. For this we might have been prepared; for we have already seen that the Mediterranean and Red Sea, although so near each other, have each their peculiar fauna, and a considerable difference is found in the four groups of testacea now living in the Baltic, English Channel, Black Sea, and Mediterranean, although all these seas have some species in common. In like manner, the diversity of the fossils of different tertiary formations does not always imply a distinctness

can only be considered as an approximation, but perhaps as near an one, as circumstances will permit, to a true classification; and, in consequence, it has been very generally adopted. It is, however, too uncertain a guide to allow us to do more than refer those strata in which the fossils differ most from existing types, to the earliest, those in which they differ least, to the latest, formations.

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in the times when they were produced. Thus, on the African border of the Red Sea there is a white calcareous formation containing several hundred species of shells differing from those found in the clay and volcanic tuff of Ischia, near Naples. Another deposit has been found at Uddevalla, in Sweden, in which a large portion of the shells do not agree with those of Ischia. But although, in these three cases, there may be scarcely a single shell common to the different formations, we do not hesitate to refer them all to one period (the Post Pleiocene) because the species agree in every instance with those now living in the contiguous seas. In like manner, when we have discovered a limestone in Sicily, rising to the height of 3000 feet, in which more than four-fifths of the shells are the same as those of the Mediterranean, we may regard such a deposit as contemporaneous with other strata on the Clyde in Scotland, in which all the shells, with the exception of fifteen in an hundred, are of living northern species. In both cases, the assemblage of fossils exhibits a corresponding amount of divergence from the existing state of things." —Lyell's Elem. of Geol. 2nd edit. vol. i. p. 277 et seq.

Rise of Land.

The great alterations which took place in the physical geography of the globe, during the long dark period in which the records we have been striving to decipher, were accumulating, were attended not only by important changes in organic life, but also by a considerable difference in climate, of which the fossils of that date afford ample proof.* As we compare the successive tertiary formations, we may trace, both in the animal and vegetable remains there embedded, a constant increase of species fitted for our present climates; exhibiting thus a progression from a state in which extinct species and even genera predominate, to one where they assimilate more and more with those now existing. There are signs of a great increase of land, in European and North American lati-

* When viewing with astonishment the enormous skeletons of animals belonging to *families* of genera at least, with which we are acquainted, we are apt to forget the influence of climate on *size*. The scorpion of the West Indies, in the present day, is a monster compared with that of Italy, so is the centipede; and the difference between the dray horse of London, and the Shetland pony is not less remarkable.

tudes, during all the Tertiary Periods ; and two-thirds of modern Europe have emerged since its earliest group was formed, though some tracts of land in the same region, have, by a contrary action, sunk below their former level. Recent observations have disclosed the wonderful fact, that large areas of many thousand miles in circumference on the west coast of South America, in Scandinavia, and in Polynesia, are slowly and insensibly rising; while Greenland, and other parts of the Pacific and Indian Ocean, where coral islands abound, are as gradually sinking.

It seems scarcely to be doubted that all lands have originated in such movements; the denudation they appear to have suffered everywhere, is in favour of the theory of their having been raised from the sea by successive upward movements, through indefinite periods: for the action of waves and currents on land in this state, is indeed the only power capable of hollowing out deep valleys, and sweeping off whole strata from large areas, as has evidently been done in many places, where isolated patches, as it were, remain on a plain from which all the rest of the same formation has been carried off.

Much of the wide Pampas plains of South America has emerged from the sea at a very modern period; the land at the North Cape of Europe is said to rise about five feet in a century; proceeding south, the movement diminishes first to a foot, and at Stockholm to three inches in a century: still farther south, this movement ceases entirely. In other places the elevation is sudden, as in the province of Cutch in the East Indies, where a large area was found to have risen eleven feet during a severe earthquake. In England the Tertiary strata are heaved up in two great swells, with anticlinal axes; one dividing the London and the Hampshire basin, and the other, which appears to have been more violent in its effects, runs across the Isle of Wight, where the magnificent scenery of Alum Bay shews the Eocene beds resting on the chalk rocks of the Needles, not horizontally, as originally deposited, but in a vertical position, which they have *both* been thrown into by the same force acting from below. The Jura chain also has been thrown up after certain of the tertiary beds had been deposited: and the group of the Andes, like the rest of the continent of South America, seems still to be undergoing changes from active causes, which may give some notion of the mode in which such causes operated in past ages. Humboldt's account of the emergence of the mountain of Jorullo* on Sept. 29th, 1759, from a plain till then cultivated with indigo and sugar cane, is well known. This event was preceded by 90 days of earthquakes and subterranean thunders: and he records it also as a common tradition that the gulf of Cariaco owes its existence to a rent of the continent, attended by an irruption of the ocean, shortly before the third voyage of Columbus, when it was mentioned by the natives as a recent event.†

In Patagonia, which stretches away towards the southern extremity of that continent, Mr. Darwin observes, that "there are proofs that the whole coast has been elevated to a considerable height within the recent period. Several steps of elevation, covered with rounded gravel, being found far inland; as if the sea beach had been raised at successive periods. These steps are often several miles broad, and the shingle covers the entire surface of the land from the Rio Colorado to the straits of Magellan, a space of 800 miles. He had reason to think that this

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* It is elevated to 1580 feet above the level of the surrounding plain. Humboldt's Kosmos, vol. i. p. 218.

† Humboldt's Pers. Narr., vol. ii. p. 214.

shingle everywhere extended to the foot of the Cordillera.* In Chili, an elevation of two or three feet had taken place during an earthquake.

Metallic Veins.

Although the *period* at which metallic veins were introduced into the places where they are now found, must always remain somewhat obscure; the *mode* of their introduction is no longer a matter of doubt. They are never found but in the neighbourhood of igneous rocks, and have therefore been either inserted between other strata in a fused state, or have percolated in a state of solution, as metallic salts. Iron appears to have shown itself the earliest; for the red sands of the Devonian system derive their colouring matter from that metal; and the rolled lumps of magnetic iron ore, found in the sedimentary Permian deposits, could only have had their origin in the Ural, from which these deposits appear to have been derived: indeed this is made sufficiently evident by its being found there in considerable quantity; sometimes in the form of dykes, which traverse the other rocks; sometimes deposited in hollows, and filling up the inequalities, as if it had flowed over

* Darwin's Journal, &c. of H. M. S. Beagle, p. 203.

in a melted state.* It is evident that when thus associated with igneous rocks, metals may be intruded into other strata at any period after the deposition of these latter. Most probably the *lodes*, or thick beds of metallic ore, which are introduced between strata, have flowed hither in a stream; while the small crossing veins, which frequently run at right angles to the lode, may be owing to electric or magnetic action. Copper seems to have made its appearance soon after iron; but Gold and Platinum are not found until the Tertiary Period. The latter is scarce; the former, though far less abundant than many other metals, has been tolerably abundant in South America, where it is found in granitic and quartzose rocks, and in the Ural, where it is chiefly found disseminated in a coarse detritus evidently formed by the action of water on the rocks in which it had its site. Where gold is found, diamonds very frequently occur, though not generally in the same matrix. It would seem as if they were generated by igneous action in metamorphic rocks, much in the same way as garnets appear to be between the flakes of mica schist.†

* Geol. of Russ. vol. i. p. 371, 394.

† A different view of the origin of diamonds is sug-

Erratic Blocks and Northern Drift.

"From the German Ocean and Hamburg on the west, to the White Sea on the east, a vast zone of country, having a length of near 2000 miles, and a width varying from 400 to 800 miles, is more or less covered with loose detritus, including erratic, crystalline blocks of colossal size, the whole of which have been derived from the Scandinavian chain."* Various hypotheses have been formed as to the origin of

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gested in the following paragraph, which we copy from the Eighth Edition of Turner's Chemistry, edited by Baron Liebig and Dr. Gregory.

"It is probable that the decay of lignine under certain circumstances, may proceed to this extreme point;" (viz. "till all the hydrogen had been removed" and only carbon was left.) "And if the carbon should be separated in a liquid, or in such a situation as to allow the particles to arrange themselves freely, it might crystallize, and thus yield the diamond. At all events, no other means are known by which diamonds can have been produced; and the recent discovery of the skeletons of organized tissues in the ashes of the diamond, which are the ashes of impurities enclosed in the crystals, has greatly added to the probability of this view of the origin of the diamond." Turner's Chemistry. Eighth Edition. Part 2, p. 1239. Geol. of Russ. vol. i. p. 481.

* Geol. of Russ. vol. i. p. 507.

this phænomenon; but as, in a work of this kind, the writer must exercise his own judgment in deciding between conflicting authorities, for readers who have not the time or means to examine the question deeply, he thinks none will blame him for having leaned to the opinion of Sir R. I. Murchison, whose large opportunities for observation, and high reputation, sufficiently justify such a preference.

"The superficial detritus of Russia, Poland, and Prussia," observes this gentleman, "like that of other great regions which we have examined, is referable to the great mountain chain in its vicinity. The chief distinction between it and all other far borne drift, consists in the great breadth and length of the dispersed detritus, in reference to the low mountains from whence it has been derived; for whilst, in other parts of Europe, various local centres of elevation have shed their detritus in different directions, (England, France, and the Alps offer sufficient examples); the vast regions under consideration have been uniformly covered with crystalline materials, which have proceeded from Scandinavia and Lapland only." Some of the blocks thus transported are rounded as by the action of water; but many have retained their angles so unbroken, that they must have been deposited in their present site by some agency independent of the wash of the tide. It is farther remarkable that this drift usually occupies high plateaux, leaving the lower grounds unencumbered, or vice versâ; and that in those parts of Europe where these erratic blocks are found, the northern face of high ridges, or cliffs, are found to be ground and polished as it were by friction, or marked by furrows as if abraded by some hard, sharp substance. Sir R. Murchison taking these circumstances, and many other corroborating ones into consideration, supposes that the countries where these blocks are found must have been under water at the time they were deposited there, the rounded ones by the action of a great wave of translation: the angular, by the agency of icebergs, which, detaching themselves from the cliffs of Scandinavia, were floated onwards until they grounded where the sea was shallowest, and there gradually deposited the stones and earth with which they were charged, as they melted. The subsequent upheaval of the sea bottom by a gradual rise, such as is still going on in that part of the world, would still keep up the relation of high and low ground; and thus the blocks which were deposited in shallow water, are now found on raised plateaux. Where, on the contrary, this detritus occupies low valleys, and the high ground is free, it is likely that these valleys were bays surrounded by ground already emerged from the ocean, and that the ice was driven in by the winds, and there stranded and melted. This view is corroborated by the fact, that in no instance are there blocks or boulders, as they are called, to be found near the Ural. They appear to stop short at that part where the later marine deposits are wanting; thus giving reason to suppose that this part of the country, which probably was raised above the sea level by the same causes as threw up the Ural chain, and many others, at the same period, afforded a barrier to the northern detritus. Some great change in the position of the northern lands would sufficiently account for a succession of enormous waves, such as have been witnessed sometimes, in the case of earthquakes, even in our own times. The striæ upon the rocks against which these northern waves propelled ice flocs, loaded with sharp pieces of crystallized rock frozen into their sides and bottom, would be but a natural result. It may be added, that in the gravel and sand which accompany these erratic blocks, recent species of marine shells belonging to the arctic seas have been found, thus affording convincing proof that the operation was oceanic, and probably not very remote.

In other parts of Europe, where blocks are found apparently detached from mountains not many miles distant, the action of glaciers, of torrents, and of such accidents as occurred not many years ago in the valley above Martigny, may all have had their share in the transport.

Fossils.

During the early part of the Tertiary Period the same high temperature which was evinced by the fossil plants of the Carboniferous epoch seems still to have prevailed. Those of the Isle of Sheppey, of which we possess abundant remains belonging to this epoch, are all of genera common in tropical climates, but at present unknown in the north; such as palms, acacias, gourds, and some plants of the family of Nipæ, which are now found chiefly in the Spice Islands and Japan, growing in marshy tracts, near brackish waters. This luxuriant vegetation appears to have nourished an abundance of animals so enormous, that we can scarcely figure to ourselves what a world would be, over which such monsters roamed at will. Certainly it would have been ill-fitted for the abode of man.

The larger part of these monsters appear to have belonged to the family of Pachydermata, or thick skinned animals, of which some large species yet remain; such are the elephant, the rhinoceros, and the hippopotamus: but the animals which have left their remains in the Tertiary beds were many of them even of a larger size than the largest of these. One called *Dinotherium*, which seems to have been aquatic in its habits, is calculated from the size of the bones found to have attained a length of eighteen feet: it bears a considerable resemblance to the Tapir, in its general form; but had two singular tusks in the lower jaw, turning *downwards*, which seem to have been used as pickaxes in rooting up plants; and is supposed to have been provided with a short trunk for collecting the food thus grubbed up. The bones have been found in the Miocene beds of the valley of the Rhine at Eppelsheim.* The Mastodon, whose bones chiefly occur in North America and Asia, but sometimes in Europe, appears to have nearly resembled the elephant, but to have lived on softer and

* Ansted's Geol. vol. ii. p. 84.

more succulent plants—probably it found its subsistence in swamps. The Mammoth, or elephant of Siberia, was clothed with thick hair,* as was seen when the breaking away of a river bank in that country, disclosed a carcase which had been frozen in, with the flesh and hair adhering. This was discovered in 1799, and a rhinoceros tichorhinus was discovered by Pallas, not far from the same place, with the skin and hair also adherent to the sides of the head. These animals could not have belonged to a *very* remote period, however much the climate may tend to the preservation of animal substances.

In South America the fossil bones have a family likeness to the genera still found there; though most of them are of enormous size. The edentate animals† preponderate, and at the head of them stands the *Megatherium;* an animal of the sloth kind, whose bones greatly exceed those of the elephant in size; having a length altogether of nineteen feet, a breadth across the loins

* This provision for a colder climate was accompanied by a form of tooth which enabled the animal to grind down even wood for its subsistence.

† The Edentata of Cuvier comprise the sloth, armadillo, ant-eater, manis, &c., and two of the anomalous animals of Australia.

of six feet, a height of about nine feet. I have not space for enumerating the various animals whose bones have been examined and classed, and which gradually approach existing types.* An interesting account of them will be found in Prof. Ansted's "Ancient World."

It was not till very lately that any remains of the family of Quadrumana (monkeys) were found, and even now they are rare, as are those of birds, whose small and porous bones, unless by chance thrown into the water, are soon decomposed and perish. One bird of enormous size seems to have existed in New Zealand, even within the traditional period of the natives. It was wingless, and must have exceeded the Ostrich in size. The fish of the Tertiary beds still show a few of the ancient order of ganoids, but the species are few, compared with those assimilated to more modern types.

* The researches of the Rev. W. V. Harcourt, and of Mr. H. E. Strickland have shown (the former at Market Weighton, the latter at Cropthorne, on the Avon), the co-existence of the mammoth, bos urus, rhinoceros, hippopotamus, lion, bear, tiger, hyena, deer, &c. (all of species distinct from those in existence) with land and fresh water shells, nearly all of which are identical with species not living in Britain. See Proceedings of Geol. Soc. 1834, and Phil. Mag. Sept. 1829 and Jan. 1830.

Conchology is a science by itself, and though of infinite importance in Geology,* is too complicated as we approach modern times, to allow of a *short* notice of Tertiary shells, which, even as far as yet discovered, amount to 3036 different species: but it is impossible wholly to pass over the minute Infusoria, which have already been slightly noticed under the head "Rocks," in the Definitions. Let me be allowed to quote Professor Owen, as to their use in creation. "Consider," he observes, "their incredible numbers, their universal distribution, their insatiable voracity, and that it is the particles of decaying vegetable and animal bodies which they are appointed to devour and assimilate.

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* How times change! it was only in the year 1819, that a wit of the day wrote

———"engage him in some useless study;
Which may absorb his wits if he has got any:
'Twas thus a prince of Naples was taught botany.
Of such an end could such a science miss?
For sure there is none other but conchology
That is so mere a *cul de sac* as this."

Rose's Court of Beasts.

I believe the period for gibing at science is nearly as much past as the Secondary Period of rocks: and the above quotation is a *fossil*, showing the odd conformation of wits in former years. It may be laid up in a cabinet with Butler's "Elephant in the Moon."

"Surely we must in some degree be indebted to these ever-active invisible scavengers, for the salubrity of our atmosphere. Nor is this all: they perform a still more important office in preventing the gradual diminution of the present amount of organized matter upon the earth. For when this matter is dissolved or suspended in water, in that state of comminution and decay which immediately precedes its final decomposition into the elementary gases, and its consequent return from the organic to the inorganic world, these wakeful members of nature's invisible police are everywhere ready to arrest the fugitive organised particles, and turn them back into the ascending stream of animal life. Having converted the dead and decomposing particles into their own living tissues, they themselves become the food of larger Infusoria, and of numerous other small animals, which in their turn are devoured by larger animals: and thus a pabulum fit for the nourishment of the highest organised beings is brought back by a short route from the extremity of the realms of organized matter. These invisible animalcules may be compared in the great organic world to the minute capillaries in the microcosm of the animal body, receiving organic matter in its state of the minutest subdivision, and when in full career to escape from the organic system; and turning it back, by a new route, towards the central and highest point of that system."*

I HAVE now brought to a close my slight sketch of a subject so abundant that volumes would scarcely do it justice. Much of interesting matter has inevitably been omitted; but if enough has been given to tempt the reader into a deeper study of it, the object of the work will have been gained. One thing can hardly fail to strike him, even upon this cursory survey of the work of creation,—and that is, the evident preparation for something higher in organization, and nobler in purpose, than probably has ever yet been seen. Whatever apparently accidental changes may have taken place, — however races may become extinct, and fresh ones supply their place,—we find one thing constant, *i. e.* a progressive advance towards per-

* Owen's Lectures on the Invertebrata.

fectionizing that system of brain, and nerves co-operating with it, which ministers to the higher exertions of intellect. The Brachiopoda, so abundant in the earliest formations, are also among the lowest forms of organization in this respect; and the nautilus, though belonging to the order of Cephalopoda, is inferior, thus far, to its congener, the cuttle-fish, in which the rudiment of a cerebrum is seen, and which has its representative only in the Belemnite of a later age. The progress towards the developement of the hemispheres of the brain, the great organs of intellect, through fish, reptiles, and birds, up to mammalia, is continuous; and it may be observed that even of this last class, those which first appear have the least complex brain. Thus we see, amid apparently fortuitous convulsions, a steady advance towards one great end, till we at last arrive at the introduction of man upon the earth, which had been prepared for him by so many successive stages; with organs fitted for a still greater progress than he has yet made, and aspirations for more than even those organs afford room for. We have seen that progress is the law of creation—can we doubt that we see in the past the pledge for the future; and that as the ages of an unmeasured past were spent in preparations for a body fitted to receive a divine principle; so the ages to come of an immeasurable future, will see the gradual advance of that principle from its first weak developement here, through continued stages of power and felicity. So long a preparation was not made for a being whose "thoughts perish" at the end of a few years. There is pleasure in this: there is pleasure in reading off from the tablets of God's works the confirmation of his word: in seeing ourselves part of a system in which though thousands of years be but as one day, each divine day, nevertheless, brings with it an advance in the scale of being, and leaves room in the immense perspective for the largest hopes which we have been encouraged to form.

THE END.

C. WHITTINGHAM, PRINTER, CHISWICK.